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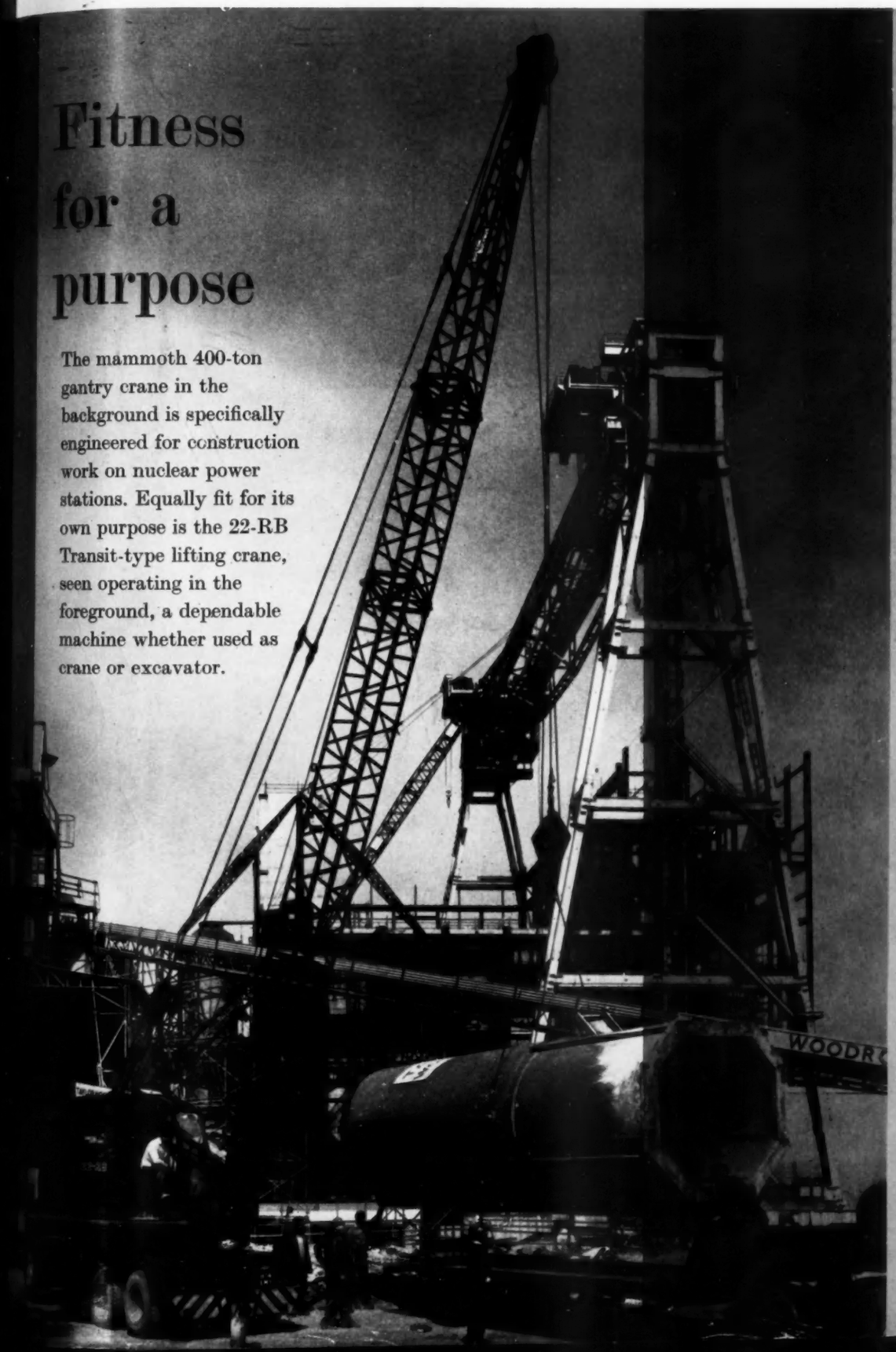

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No. 5518 **OCTOBER 27, 1961** VOL. 212

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THE ENGINEER

No. 5518 OCTOBER 27, 1961 Vol. 212

TO BUILD OR NOT TO BUILD?

The announcement by Sir John Brocklebank, the chairman of the Cunard Line, that the Company had decided to postpone the building of a replacement of the "Queen Mary" has proved a grave disappointment to those shipbuilding and engineering firms which submitted tenders for this valuable contract and to shipbuilding workers in the firms concerned. There was, of course, some doubt whether the ship would be built ever since the chairman's promise to the shareholders that the whole matter would be considered again should the cost exceed £30 million. In fact, however, the cost seems to have entered into the decision not to proceed only to a limited extent: for it is reported that the lowest tender was well below £30 million. What is evident is that even since the project was originated there has been a progressive change in passenger travel across the Atlantic. First-class passengers are increasingly choosing to travel by air, with particularly adverse effects upon earnings since the "Queens" cater primarily for first-class passengers. A recent fall in earnings in association with increased operating costs, coupled with a fuller appreciation of recent technical advances in the design of ships and machinery, as revealed by the tenders, has influenced the decision to postpone building.

Since the "Queen Mary" was designed and built long before the war substantial improvements in building techniques have been evolved and new materials, especially aluminium alloys, have made it possible to provide extra passenger accommodation without affecting stability. Even greater developments have been made in the design of machinery, involving higher steam pressures and temperatures, so that much more power can be installed in less space. Such factors do suggest that if full advantage is taken of modern techniques and materials a smaller and cheaper ship (or ships) would serve the needs of the Cunard Steamship Company Ltd. Furthermore, if it were decided no longer to concentrate on first-class passengers a ship of greater user potentiality could be built, to operate, perhaps, in association with other liner companies. When the "Queens" were laid down before the war their design, it was soon revealed, was based on hard realistic thinking. Those ships, though the largest in the world, were the smallest capable, in the light of technical knowledge at that time, of providing the speedy Atlantic service which the Cunard Company regarded as essential. In fact hard cool-headed thinking led, despite controversy, to the building of two ships which, in war and peace, have proved outstandingly successful. Now it has become obvious once more that there must again be hard cool-headed thinking of the same high order in order to assess firstly what are the real prospects for carrying passengers by sea across the Atlantic and secondly what can be done by the use of really up-to-date techniques of shipbuilding and marine engineering to provide the kind of ship or ships best suited to those prospects.

THE TWENTY MILLION POUND SMELL

Although the full report of the Water Pollution Research Laboratory has still to be published (and indeed certain work remains to be done to complete the Laboratory's researches) it is already clear that a first class piece of research has been achieved in its analysis of the polluting and purifying processes going on in the Thames estuary. Like all work of this character, the results are analytical; they establish the facts of what is actually happening, and will allow prediction of the effects of any changes contemplated. By contrast, the report of the Ministry of Housing and Local Government's committee, which is the subject of an article on page 679 herewith, although it must necessarily lean very heavily on the Laboratory's findings, seems to establish a policy for the future treatment of pollution in the estuary. As a result of the Laboratory's researches, the committee has a sound factual basis from which to start, which was novel for a situation of this kind.

Very broadly, the position is that both oxygen and nitrate in the estuary can contribute to the oxidisation of polluting substances; when both are consumed, sulphate is reduced, leading to the presence of sulphide, and the evolution of hydrogen sulphide. It is this condition which results in the noxious smells and the black water which have been complained of. The committee considers that a margin of safety over these conditions should be maintained; i.e. under the worst conditions there should be a reserve of nitrate in the river. Improvement beyond this stage will not make any material difference, until a stage of purity which will support fish life is reached. This, in the committee's view, would be exorbitantly expensive to attain, if practicable at all. Sufficient improvement at purification works to ensure a margin at all times over the "nuisance" conditions, is, therefore, the limit of the committee's recommendations, though it does suggest a further review when the Laboratory's work is complete, and the accuracy of its calculations known more precisely, and when the most important purification schemes now under construction — the L.C.C's £20 million programme at its two outfalls and the West Middlesex scheme — are complete, and the estuary has been examined with them in operation. At present, the Barking and Crossness outfalls of the L.C.C. contribute roughly half the polluting load from all sources; these two, plus the sewage works at Mogden and Dartford, are responsible for about nine-tenths of the sewage effluent in the tidal river. The improvements now being made might, in the committee's view, be enough to prevent objectionable smells, but are unlikely to provide a reasonable safety factor, but it is considered premature to suggest works for this purpose.

Admiration for the scientific skill and originality displayed by the Water Pollution Research Laboratory becomes, therefore, tempered by the unpleasant conclusions reached by the committee. It is clear that we shall see the elimination of "nuisance" conditions in the

Thames estuary within a few years as a result of this work. But will we ever see the much more inviting prospect of an estuary with fish in it? The committee thinks not. Clearly the issue is no longer scientific, or even economic, but social. How much is a community willing to pay for a clean river—for a river which might perhaps be called "whiter than white"? Is the attainment of such a goal one of the necessary things that the improved standards of life promised in the future will demand? Or will our increased wealth be concentrated more on personal luxuries? According to the committee, provided the Thames does not stink, it should be allowed to continue to flow, undisturbed and unruffled, even though heavily polluted, for many years to come. What view, we wonder, will posterity take of that conclusion.

ROAD ACCIDENTS AND ENGINEERS

There are two ways to react to road accident figures. One is the emotional way. Drivers, especially motorists, must be held to blame. They are to be declared careless irresponsible and reckless when in charge of a "lethal weapon" like a motorcar. Since the trend of accidents is upward it must be held proved that the deterrent to ill-doing on the road provided by the Law is not strong enough; so that there should be more severe penalties and multiplied restrictions and that those found guilty by the Courts should be more severely punished. Since so many magistrates and juries have proved unwilling to apply in their full rigour legal penalties already available there should be set up special motorists courts, bereft of juries, to try offenders. The punishment of taking away a driving licence should be more freely adopted. The emotional reaction it will be noticed is towards the punishment of ill-doers.

For engineers a more rational approach is appropriate. Emotive expressions like "lethal weapon" are to be avoided. Vehicles, it is true, can be lethal; but then so can lots of other things like kettles, gas and electric fires, oil stoves, flights of stairs, cricket balls, swimming pools and even in special circumstances human fists. But they certainly are not weapons since few, outside detective yarns, drive them with the deliberate intention of killing or maiming anyone. The trend of accidents, it will be conceded, is upward. According to Road Accidents 1960, just published by H.M. Stationery Office, there were 271,787 accidents involving death or personal injury in 1960, an increase of 4 per cent on 1959, and deaths on the road increased by 7 per cent. But those emotive figures should be put into better perspective; they should be quoted in the context of vehicle mileage, which is estimated to have been 7 per cent higher in 1960 than in 1959. Quoted in that way the figures provide no evidence for increasing wickedness amongst motorists; rather the reverse because another set of figures shows that over the last decade the rate of increase in casualties has been significantly lower than the rate of increase of the number of vehicles. Nevertheless the steady upward trend is deplorable and disturbing even though it provides no evidence of an increase in careless, irresponsible or reckless driving.

What can be done about it? Every highway engineer knows the answer. Accidents occur not because drivers and other road users are reckless but because they are humanly fallible; once in a while they will make an error of judgment. They are particularly liable to fail to assess that at a particular place or under particular conditions certain roads are dangerous. Under these circumstances the emotional commentator, like the unemotional but uninformed policeman who reports upon an accident, will blame the driver for "recklessly" travelling too fast. By contrast the highway engineer, more prosaically, but much more usefully, finding, as so often happens, that accidents tend to occur in certain places, labels such places black spots and examines them to find wherein lies the hidden defect which leads drivers to suppose the road safer than it really is. That defect may be a bend deceitfully sharper than any for many miles back along the road, a surface which looks safe enough when wet, but which is in fact slippery, a hidden cross-roads or the like — the sheer number of hazards on most British roads makes one exclaim at the high level of competence of British drivers rather than the reverse! Given the money, given an adequate programme not only of building motorways but of improving main highways, road engineers are well aware that they could soon reverse the trend of accidents. That there is still a rising trend in accidents merely emphasises the point made by Messrs. Drake and Kidd at the Traffic Engineering Conference organised by the Institution of Municipal Engineers three weeks ago on which we commented at the time, that at present rates of expenditure extended into the future more and more of the main roads of this country will fall below Ministry of Transport standards of width, etc., in relation to the amount of traffic they will have to carry. They will inevitably become more dangerous.

CIVIL DEFENCE

After the first test of a thermo-nuclear missile five or six years ago, it was at once clear to the Governments of both Russia and the Western countries, that a war waged with this type of missile would very soon result in the virtual destruction of the economic and civilised life of their peoples. Both East and West therefore decided that a mass destruction war of this kind must be avoided and that, paradoxically, in the absence of total disarmament the only way of achieving this object was to build up a stock of thermo-nuclear weapons. It is not moreover inconceivable that in pursuance of the aim of outstripping the economy of the capitalist countries, the Soviet leaders hoped also to encourage the West to spend money on weapons they believed would never be used. Be that as it may, this policy has — perhaps inevitably — engendered suspicion in both sides that one or other, faced with the menace to some vital interest, might be tempted to profit from the great advantage given to an aggressor. The United States—which feels chiefly responsible for preventing a thermo-nuclear war — thus attaches particular importance to maintaining a "strike-back" capability which requires different types of deterrent bases adequately protected from unexpected attack. Government and military leaders have for this reason endeavoured to convince the United States people that a country of such a vast area could and should be prepared to carry on a "broken back" war until the aggressor is obliged to surrender.

Though bombers and rockets of intercontinental range and missile-carrying submarines have much reduced the safety factor hitherto provided by distance, the American people have continued until recently to pursue their lawful occasions without giving much thought to the situation that would arise in the early stages of a Soviet offensive. Nor has the United States Government done much to encourage them to do other-

wise. No plans were in evidence for the construction of underground shelters and for a national economy based on regional areas with underground branch factories to provide minimum requirements of the Armed Forces. The Berlin crisis has however brought home to the Government its responsibilities, as a Member of N.A.T.O., for safeguarding the N.A.T.O. peoples from aggression; and the provision of shelters is now arousing more general interest and is also in fact under active consideration by the American Government. It is even being suggested than in view of the immense stockpiles of nuclear missiles now available in the United States, the £1,000,000 expended on developing a rocket which explodes shortly after taking off would be better spent in building shelters each holding some 20,000 people. Conditions in Britain—both economical and geographical —are of course wholly different and the impracticability of organising and setting up passive defence facilities adequate to protect the whole civil population is generally recognised. None the less the impracticability of doing so is used as an argument by the unilateralists for Britain having no N.A.T.O. deterrent bases in this country at all—an argument which is completely fallacious. It should, however, be made quite clear that the building of a large number of deep underground shelters sufficient to save the lives of a substantial proportion of the population is by no means impossible, though it would be very costly. Shelter design and construction is basically a civil engineering task and it is certainly not the fault of Britain's civil engineers that underground shelter building on a large scale has not been undertaken. To undertake it would, however, be a departure from the principle, which this country has followed throughout its history, that the best form of defence—and under modern conditions this means the best method of ensuring survival — is offence. The Soviet leaders know that, with the early warning systems and radar facilities, British V-bombers will be airborne in good time to assist the United States Strategic Air Command in inflicting even more damage than the Soviet bombers and rockets can inflict on both countries. It is this ability to make a counter attack simultaneously with the enemy attack which is the best defence. But Britain could not continue to maintain this ability if it were to spend many millions of pounds, and divert the immense resources required, in an effort to provide for a situation which is, by hypothesis, unlikely to arise. As for extending civil measures to the building of branch factories and organising industries to continue operating after heavy attack from thermo-nuclear missiles, this would be futile. The heavy industries of the United Kingdom—a country very small in area in relation to the destructive effects of an H-missile—are concentrated around a relatively small number of towns and few if any are likely to survive the first series of salvos from the 40 odd intermediate range rockets which are believed to be earmarked for attacking this country.

LONDON INTERNATIONAL ENGINEERING EXHIBITION

It has just been announced that an international engineering exhibition is to be held at Olympia and Earls Court in London from April 23 to May 2 next year. This exhibition is being organised jointly by F. W. Bridges & Sons Ltd., which has since 1906 been responsible for the biennial exhibition variously titled and called last year the Engineering, Marine, Welding and Nuclear Energy Exhibition, and Industrial and Trade Fairs Ltd., the organisers of the British Trade Fair in Moscow earlier this year. It is designed to partly overlap the period of the Hanover Fair to enable buyers from all parts of the world to see both events in one trip to Europe, and to draw foreign buyers on a scale compared to that of the biggest fairs in Europe. The whole of the space available at Earls Court and Olympia, totalling about a million square feet, is to be occupied by the exhibition and we understand that 1200 exhibitors from this country and overseas are expected to participate. Exhibits will range from large items of capital equipment to components; the heavier exhibits being displayed at Olympia and the lighter products and electrical equipment at Earls Court.

There is little doubt that an international exhibition of this kind in this country is much to be desired; but it will, once again, show the country's need for a large exhibition ground and new halls on a single site — for large as they are, the combined facilities of Earls Court and Olympia fall short of those at Hanover, Brussels, Milan and Leipzig. If the new exhibition emphasises these facts, and leads to official steps being taken to meet the need for exhibition buildings and grounds commensurate with the industrial standing of this country, it will achieve an important purpose.

The Engineer—100 Years Ago (OCTOBER 25, 1861)

Fresh Water at Sea

There have been many types of apparatus for distilling salt water on board ship and so providing a constant supply of fresh water. One such apparatus, invented by Douglas Hebson and William G. Ramsden, of Liverpool, is described in our issue of a hundred years ago. It consisted of a cylindrical vessel for containing salt water, and having inside it, at the bottom, a circular pipe connected to a source of steam, and perforated to allow the steam to be injected into the salt water. Steam could be supplied to the apparatus direct from the ship's boiler, or exhaust steam from the donkey engines could be used. If the steam were taken from the boiler it was suggested that it should be superheated by passing the pipe through the furnaces or boiler uptake. A blow-off cock at the bottom of the vessel enabled concentrations of salt water to be removed from time to time.

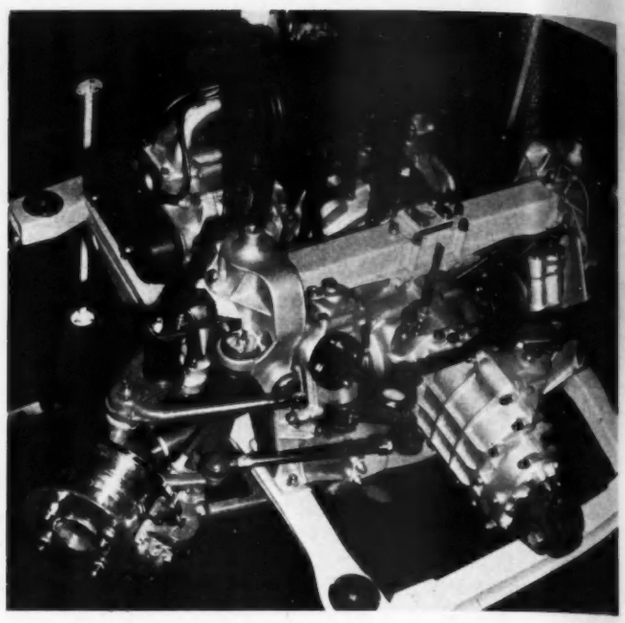
At the top of the vessel, protected by an internal domed plate to prevent priming, was an outlet pipe which conveyed the steam to some form of condensing apparatus. This could be a "... worm or other arrangement of pipes immersed in cold water ...," or "... in the case of steam ships fitted with surface condensers, the said exit pipe from the evaporating vessel may be connected directly to these condensers, by which means a partial vacuum will be maintained in the said evaporating vessel and the water therein will consequently pass into vapour more rapidly ...." Presumably, though the account does not say so, a small section of the main condenser was to be reserved for the fresh-water apparatus, in order to keep the drinking water separate from the engine condensate.

A gauge glass of orthodox type was mounted on the side of the condensing vessel, which was either to be lagged or fitted with a steam jacket. No safety valve is mentioned, or shown in the illustration, but, provided that the exit pipe was always open to the condensing apparatus, such a fitting would not be needed.

Earls Court Motor Show

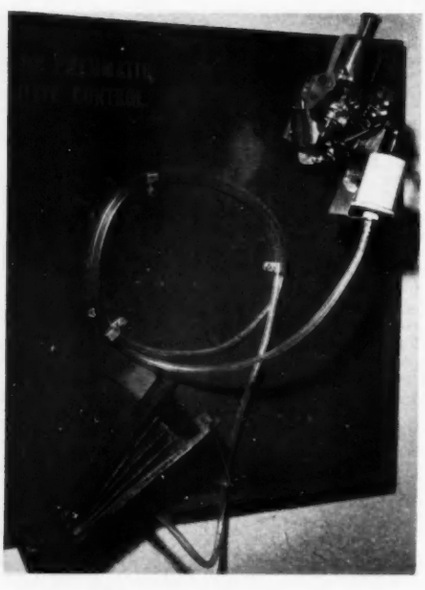
No. II—(*Continued from page 639, October 20, 1961*)

The 1961 Motor Show, which continues until tomorrow, included a number of vehicles which, while not new, had not previously been exhibited in this country. Among them was the Lancia "Flavia," the power unit and front suspension of which is seen on the right.



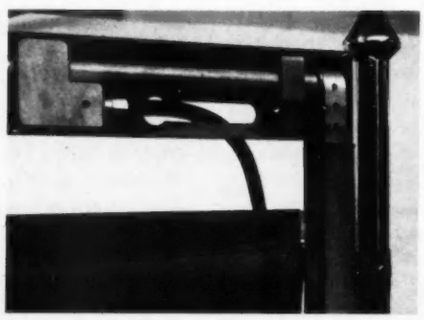
THE forty-sixth International Motor Exhibition of the Society of Motor Manufacturers and Traders Ltd. included, as we recorded last week, few cars new in fact. Complete cars constitute, of course, but a portion of the exhibits, and we continue our account of the show with descriptions of some of the components, accessories, and plant displayed, commencing with a variety of remote control devices.

The Dunlop Rim and Wheel Company Ltd. exhibited a prototype of a pneumatic throttle control (illustrated). This used a concertina-like bellows under the throttle pedal and a rolling diaphragm actuator, connected together by ¼in diameter plastics tube. Such a device is regarded as potentially less troublesome and more nearly frictionless than, for instance, Bowden cable, which demands a path with only gentle curves, while being simpler to connect and disconnect than a hydraulic system. The demonstration rig worked only indifferently, and it is understood that there have not yet been found counter-measures to gradual loss of air from the closed system and to change of pressure with temperature ; it would appear that this is inherently a mechanism with a very low stiffness.



Demonstration rig for pneumatic throttle control, showing rolling diaphragm motor

The exhibits of Broadfields Garage and Engineering Company Ltd. included the "Imperial" radiator blind, which is positively driven in both directions instead of relying upon springs to move it ; hence it can be adjusted even at high speed (when the blind is pressed against the matrix) and can be built in large sizes—blinds are catalogued for the A.E.C. "Mammoth Major" and the Leyland "Octopus." The assembly contains a pair of perforated phosphor bronze belts which run on pegged pulleys at the top and bottom of the frame. The pulleys at the bottom drive the blind roller and those at the top are driven by a flexible cable from a crank operated by the driver. The belts also carry the cross-bar to which the end of the blind is attached. The mounting for the crank handle carries a small slide which tells the driver, either by sight or feel, where the blind is set. The positive drive feature of this blind would, it would appear, allow the blind to close downwards if it is desired to have as much water as possible hot when the blind is in an intermediate position. The use of a flexible drive instead of a spring-tensioned cord renders installation problems less acute, it is claimed.



Drive mechanism of radiator blind, showing perforated phosphor bronze belt running over pegged pulley

The same exhibitor was demonstrating the adjustable fog light mounting which we illustrate. This also is controlled by a crank handle, but in this case the flexible cable works not in torsion but in tension against a spring in the base of the bracket. As the mounting moves to left or right of centre, a peg running in a profiled groove causes it to tilt downwards ; thus the light can be adjusted for good conditions or for fog from the driving seat. The user is reminded that, in this country, it is illegal to adjust it while it is alight.

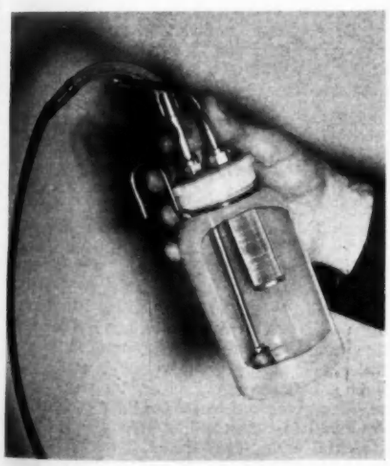
There was exhibited by Ross Courtney and Co. Ltd. the Thomas and Betts "Ty-Rap" for binding wires into harnesses or even for clamping small components such as condensers. The "Ty-Rap" is available in a number of forms, such as a simple tie for holding a bundle of wires together, a strap, as seen in our illustration, for clamping by means of a screw, or as a tie incorporating an extended surface for identification markings. There are two forms of fastening, both of which are intended for use once only—i.e., a "Ty-Rap" is not re-usable. One fastening is effected by a tool with which the tie is pulled tight—the large straps illustrated can be tensioned to 125 lb—and then twisted to jam it in the female end of the tie ; the same tool then cuts off the surplus material. The alternative fastening, intended for use in the field rather than by manufacturers, employs a metal clip on the female end which prevents the male end being withdrawn ; the tie is pulled tight by hand and the protruding end cut off. There are a number of accessories for use with "Ty-Raps," including mounting

Remotely controlled lamp mounting, showing dot generating turn-and-dip motion

Nylon "Ty-Rap" straps : the centre one has been fastened loosely so that the twisted end has not dropped back into the notch in the boss

plates to which components can be strapped, a "shoe horn" for guiding a tie round wires in awkward places, and name plates which can be attached by two ties. The ties are available in natural nylon, black, and eight colours ; they have a working temperature range of −65 deg. Fah. to 350 deg. Fah.

Temel Industries Ltd. displayed the German "Bison" brake bleeder, which enables a single mechanic to complete the operation of bleeding a hydraulic system. The principle of the device can be seen in our illustration ; the long tube leads from the bleeding screw and enters the vessel, which holds one or two pints, through a transparent tube, to allow air bubbles to be seen, and a rubber non-return valve at the bottom. The hook allows the bleeder to be hung up where it can be seen from the driving seat. When the bleeder is full, the fluid within it does not have to be thrown away : there is a fine filter on the bottom of the second pipe, and by squeezing the vessel the fluid can be delivered from the non-drip nozzle back to the vehicle reservoir. The bleeder is also available with two input

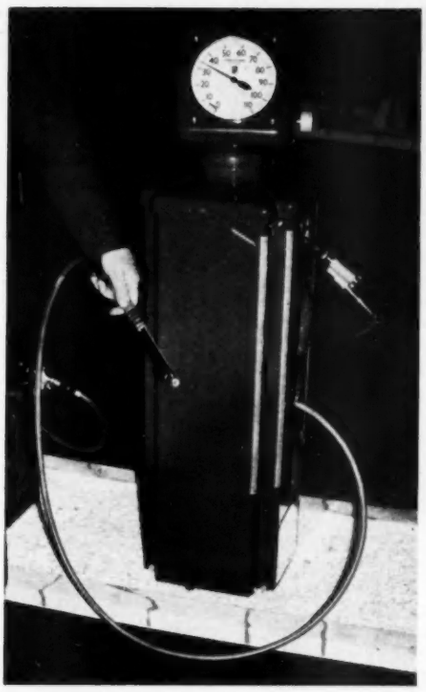


Brake bleeder incorporating fine filter to allow fluid expelled during bleeding to be recovered

pipes, for attachment simultaneously to both cylinders of a two-leading, or -trailing, shoe brake.

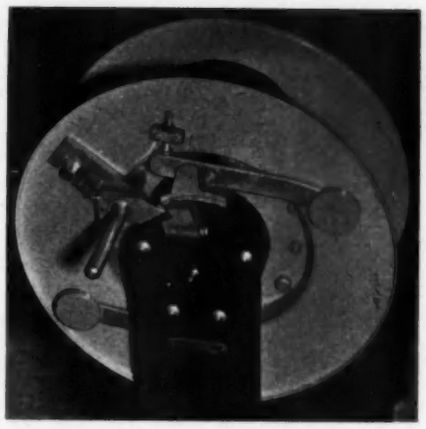
New to the market in this country was the "Redi-Spare" *in situ* puncture repair kit offered by Lexington Products Ltd. This consists of an aluminium can containing butyl rubber latex and compressed carbon dioxide. When a puncture occurs, it is necessary only to attach the canister to the tyre valve by means of a special connector which pierces the can, when the gas forces the latex—the can is held with the connector at the bottom—into the tyre and inflates the tyre sufficiently to proceed to a service station, where the normal pressure can be restored. The repair is completed by driving the car so as to spread the latex around the circumference of the tube. It may be speculated that this very simple and quick method of repairing flat tyres may allow cars to emulate the majority of single-track vehicles and do without a spare wheel.

Pneumatic Components Ltd. demonstrated on their stand the "Presetair" equipment



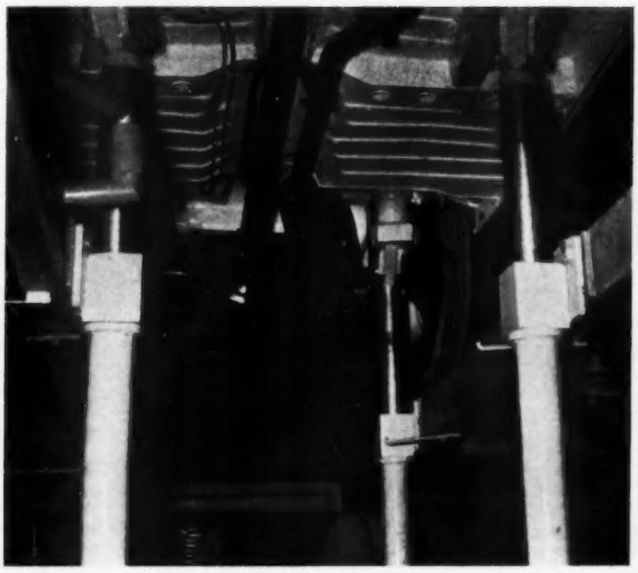
Preselective automatic tyre inflation machine, with water hose also incorporated. Notice that the hose does not have to be kept under tension

for tyre inflation. This equipment is basically an automatic balanced pressure system, in which all the operator has to do is set the desired pressure on the display head and hold the connector on the tyre valve until inflation has been completed ; so long as the pressure in the tyre is low, an alarm—a gong struck slowly—sounds. If the tyre pressure is initially correct or excessive, nothing happens when the connection is made. This system of tyre servicing has the advantage that the user does not have to make a multiplicity of meter readings, that it does not matter whether his view of the meter is obscured, that tyre pressures can be adjusted in poor light, and that the operator is "supervised" by anyone within earshot ; it is, obviously, highly attractive for dealing with vehicles on which a large number of tyres have the same pressure, such as trailers and large trucks. The rate of inflation is little slower than with a normal equipment, and the accuracy is claimed to be good.



Hose reel mechanism : the pawl has just dropped over its stop, and if the reel is now released, stop and pawl together will move to the right and come to rest

A feature of this equipment in the pedestal form illustrated is the spring-tensioned hose reel, which carries 30ft of hose. To prevent the hose being accelerated to an excessive speed when a great length is being rewound, a simple centrifugal brake is incorporated. The reel is controlled by a pawl, so that the user does not have to pull on the hose all the time ; this pawl is seen in our photograph. The reel unwinds anti-clockwise, and if the pull on the hose is relaxed immediately the pawl has been heard to fall over its stop, the reel will stay put until the hose is pulled again. If the cable is released with the pawl far from its stop, the pawl will slide back until it reaches the edge of the stop block, push the stop block to the right, drop into the gap so formed, turn through the radially inward position, and then trail the reel as the hose rewinds. When the hose is again pulled out,



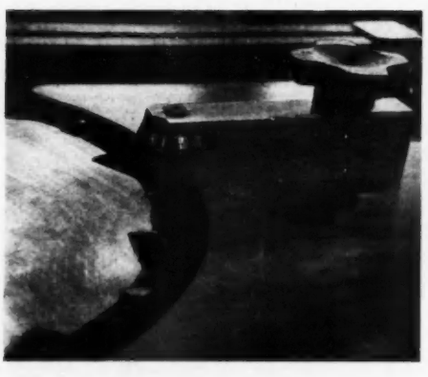
Tracked lift with wheel-free facility. Under the right-hand track can be seen the hydraulic ram which drives the lift by cables, and under the other the waste oil receptacle: oil is collected in a funnel at the top of the swivelling tube in the foreground

Rotary broach for generating plane surfaces : the work is held by the teeth of the clamps

the pawl will return to its original attitude in a similar manner.

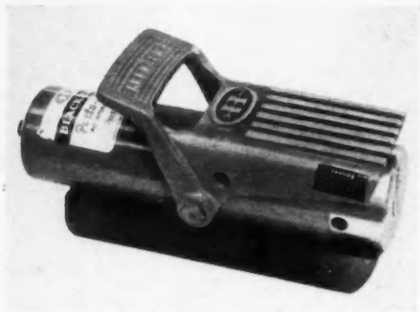
A new development of a familiar and essential device was exhibited by A. Schrader's Son ; the Schrader valve core is now made with a seal of " Teflon " instead of rubber. The new valves can be distinguished by the ease with which they can be screwed home ; the P.T.F.E. seal will have the advantage that valve cores will no longer be liable to bond to their housings when the valve becomes hot due to prolonged fast running.

There was displayed by Mann Egerton and Co. Ltd. a vehicle lift which, without undue elaboration, combines the essential features of tracked and wheel-free lifts. Basically it is a four-post lift requiring no excavation to house it, and the vehicle is driven on and raised head-high in the usual manner. Then four columns sliding in trunnions pivoted to the tracks are swung down and located in sockets in the floor, pads sliding along arms at the tops of the columns are located under the appropriate points on the vehicle—this can, of course, be done much more readily than when the vehicle is on the ground—and the tracks lowered to transfer the weight of the vehicle from the hoisting mechanism to the solid columns. Stops on the columns arrest the tracks after they have dropped a few inches, so that, if one of the columns or arms breaks, the vehicle will be supported by the nearest wheel dropping on to the track. While the vehicle is supported wheel-free, the tracks both afford means of access to the cabin and act as convenient benches for mechanics working under the vehicle.



Setting device for locating tips in broach cutter : the socket screw clamping the tip can be seen

E. P. Barrus (Concessionaires) Ltd. demonstrated the Van Norman rotary broach for generating plane surfaces. We illustrate the broach set up to face a cylinder head ; the head was set up by placing it on the moving table in which the cutter is set and then clamping it with the edged bars seen straddling it. The cutter is then started, set to the depth of cut desired, and fed from one end of the work to the other. (In the setting up the work piece is supported on a few pieces of shim, so that there is a clearance between it and the moving table). A single pass is claimed to produce a surface satisfactory as a cylinder block-to-head joint. This high



Air-operated pump for actuating hydraulic equipment

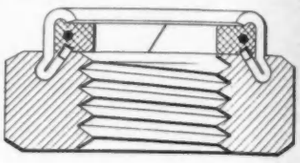
standard of finish requires, of course, that the tips of the cutter shall lie accurately in the same plane ; each tip is loaded outwards by a spring and clamped by a socket screw, and a jig is provided for setting the tips with micrometer accuracy, as seen in our illustration. A tip-grinding fitting is also offered. It is claimed that, because of the facility of setting up afforded by embedding the tool in a table, a workpiece can be surfaced in as little as ten minutes.

There was shown by Blackhawk Ltd. an air-operated hydraulic pump which serves as a " third hand " for mechanics using " Porto-Power " or " Damage Dozer " equipment to push or pull damage out of a structure. The pump runs off an ordinary air line, and the user can hear the individual exhaust pulses and thereby judge whether the ram to which the pump is connected (by, of course, self-sealing couplings) is exerting much or little effort. The pump will accept input pressures up to 180 lb per square inch and has a pressure ratio of 95 : 1, i.e. a nominal delivery pressure of 7½ tons per square inch. Pushing the control treadle in the opposite direction to that for pumping releases oil form the output to the integral reservoir.

Trolley for moving heavy (10 cwt) racks : notice that the rear ramps serve to lift and lower the hooked arms

For the transport within a works of engines and other stores weighing up to 10 cwt, Truepoint Motor Accessories Ltd. has introduced the " Bin-Mobile " trolley. The engine or other load is mounted on a special base with rollers to run on rails on the trolley, and a pair of arms on the trolley engage pick-up points on the base and allow the user to wind the base on to or off the trolley. The principal advantage of this equipment over the conventional lift truck is its low cost ; the crank handle, for example, is a kick-starter lever.

The Parr Equipment Company Ltd. exhibited the fabricated self-locking nut of Parlox Ltd. In this design the locking device is added to the nut instead of being formed integrally, thereby allowing advantage to be taken of the high production rates, and consequent low cost, of normal nuts, or, alternatively, avoiding turning away metal to form a shoulder above the hexagon. Locking is effected by a ring of nylon through



Nylon-insert locking device for addition to existing nuts

which the male thread has to cut its way ; the nylon is extruded round a steel reinforcement, so that there is no risk of the nylon being dragged from its housing. The Parlox device can be added to existing nuts, or nuts can be supplied with it fitted ; prices are available for standard or thin nuts up to 4in diameter plain, zinc plated, or cadmium plated.

Resistive Oil Heater

It may be recalled that there has been available from Power Frequency Heating Ltd. a battery charger for road vehicles in which the transformer is immersed in the engine oil and so designed that the iron losses are large enough to effect heating of the oil and hence facilitate starting (see page 847, May 31, 1957). This heater had the fundamental advantage that the greater part of the heat was evolved in the steel tube containing the oil, and hence heat transfer was unhindered and only low temperatures were needed. There were also, however, disadvantages, principally due to the large size of the active element, which demanded that it be installed outside the sump ; often there was no space available around the engine, the need for two separate holes in the sump called for a certain degree of accuracy in installation, and there were heat losses of significant magnitude to the atmosphere. In order to produce a small heater which can be mounted within the sump so that only one hole need be made there has now been developed a resistive heater, which has the incidental advantages that the wattless currents are much reduced, allowing lighter supply cables, and that it can be run off a d.c. main. The heating element is a spiral conductor insulated with magnesium oxide and sheathed in copper, and it is enclosed in a short tube, open at both ends, which is mounted, inclined at a shallow angle, within the sump.

The new heater is available in 100W, 150W and 250W sizes and for normal, 110V or 50V supplies. Where a.c. supplies are available, a conventional battery charger is available for inclusion in the circuit. The mains connection may be made in the cab or, if it is desired to be able to drive away without previously disconnecting (as is the practice with fire appliances), by an all-weather connection at the tail. Although the re-designed heater makes no use of electromagnetic induction it is still known by the name " Peregrine."

Pollution of the Tidal Thames

The Ministry of Housing and Local Government's departmental committee which has been deliberating on pollution in the tidal Thames since its appointment in April, 1951, has now published its report. The factual basis of the report has been provided by long and original researches at the Water Pollution Research Laboratory, which were briefly referred to in our last issue. The report surveys the history of pollution in the river, the causes of recent deterioration, and the effects of such factors as the presence of detergents and heated discharges from power stations. The abstracts from the reports reproduced hereunder concern an explanation of the processes going on in the polluted river, and the committee's views on the standards of purification to be sought.*

NO deliberations of ours would have been necessary to show that the way to improve a polluted river is to pollute it less, and we were quite prepared to accept that any scheme which improves the quality of an effluent would contribute to the desired end. It seemed almost as obvious—and greater knowledge has strengthened the view—that there is no foreseeable hope of restoring the Thames estuary to a completely unpolluted condition. Our main task, therefore, once the the importance of the various discharges had been assessed, was to consider how much improvement would be reasonably practicable and the ways in which this could be achieved and maintained without hit-or-miss methods or unnecessarily great expenditure.

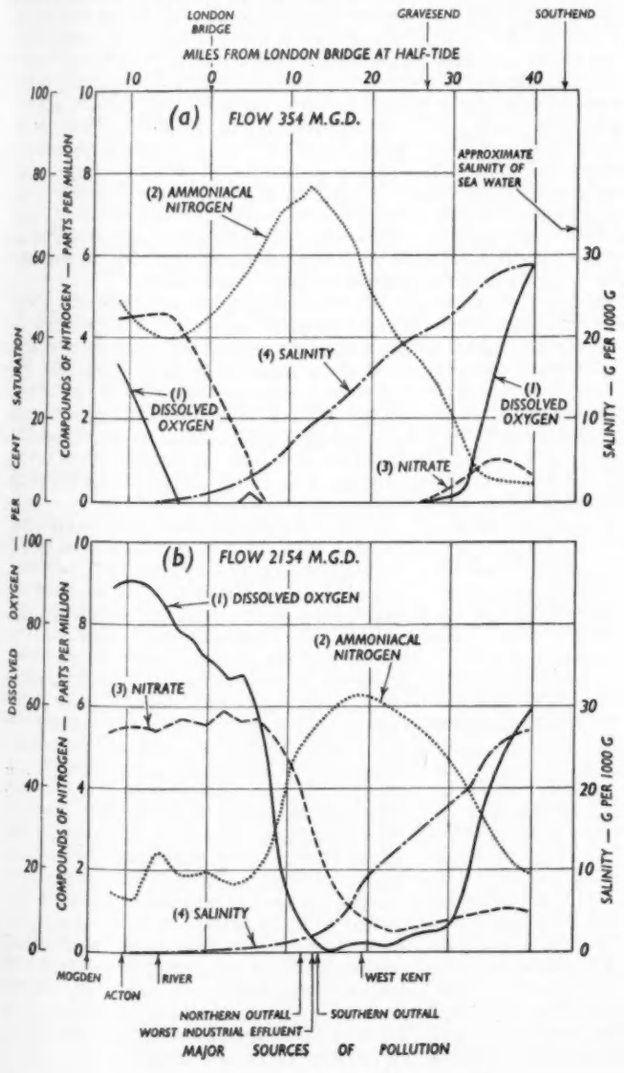
It has not been possible to allot an exact share of blame to each cause of the deterioration which has taken place. Although records of the condition of the Thames itself are probably more complete than for any other estuary, there is a lack of detailed knowledge about the discharges into it in the earlier years ; without this there could be no hope of answering the question with any precision. And yet much fundamental knowledge has been gained about the processes of pollution and purification in rivers and estuaries ; the significance of each source of appreciable pollution in the Thames estuary has been separately assessed by the Water Pollution Research Laboratory ; the effects of heated effluents and of changes in freshwater flow are now much better understood ; above all, the Laboratory have made considerable progress with a method for calculating (subject to certain reservations) the changes which can be expected to result in the estuary, under given conditions of flow and temperature, from any alteration in the various effluents going into it or in the point at which any such effluent is discharged. An important step in the development of this method was the elaboration of a theory of the mixing and movement of water in tidal rivers with similar characteristics to the Thames (that is, in which there is little difference in salinity between the water near the surface and that near the bottom).

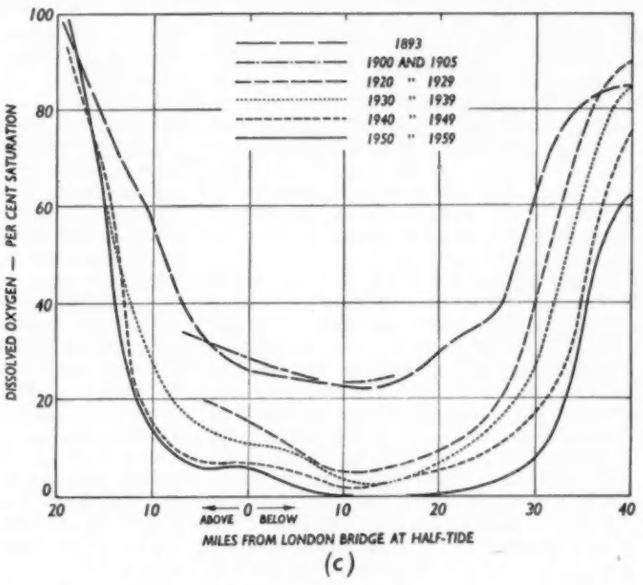
The probable effects of the principal changes since 1951 have been calculated ; as is indicated later in our report, the purification schemes completed in the last few years together with those now in progress should be just about enough to prevent the occurrence of offensive smells in the estuary.

* "Pollution of the Tidal Thames." Report of the Departmental Committee on the Effects of Heated and other Effluents and Discharges on the Condition of the Tidal Reaches of the River Thames. H.M. Stationery Office. Price 5s. 6d.

Oxygen in Rivers and Estuaries

Clean river water contains oxygen dissolved from the air to the extent of about 10 parts per million (or 1 lb in 10,000 gallons) when saturated. The oxygen content may be deleted by being consumed in the oxidation of organic matter, largely through the agency of bacteria. This matter enters rivers chiefly in sewage and sewage effluents, but both animal and vegetable matter may also be present from other sources. The two most important oxidisable constituents of organic matter are carbon and nitrogen. Carbon, on oxidation, forms carbon dioxide, organic nitrogen, after conversion to ammonia, is oxidised to nitrate. A few industrial discharges contain substances oxidisable in rivers by purely chemical action : one such





Distribution of dissolved oxygen, ammonia, nitrate and salinity on (a) August 31, and (b) February 23, 1954. (c) Oxygen sag curve during successive decades for third quarters when flow at Teddington was around 250 m.g.d.

substance is the sulphite discharged in the wash-water from the Battersea and Bankside power stations.

River water, even in the presence of sewage or sewage effluents, is capable of supporting fish life unless the concentration of dissolved oxygen falls to less than about one-third of saturation or the effluents contain toxic substances in quantities great enough to be lethal in a river. The water will not give rise to smells until the available oxygen has been reduced to zero, provided that the effluents do not contain specific malodorous substances.

Treatment of sewage and organic trade wastes before discharge is aimed at reducing their content of organic matter and consequently their demand on the oxygen in the river. The processes carried out at sewage treatment works may be subdivided into primary treatment—sedimentation to remove the greater part of the suspended solids—and secondary treatment, by percolating filters or direct aeration processes, to oxidise organic matter in the effluent from the sedimentation tanks. At a number of the works on Thamesside, only primary or partial treatment is given. In a modern works giving full treatment, much of the organic carbon remaining after sedimentation, and part of the nitrogen present in the form of ammonia (in the best works, most of the carbon and ammonia) is removed or oxidised before the effluent is discharged. Most of the carbon which undergoes chemical change is converted to carbon dioxide, which escapes to the air ; the ammonia is oxidised to nitrate, which remains in solution.

Oxidation of such matter by bacterial action will be continued in the river, if oxygen is present in an accessible form. This does not only mean dissolved oxygen ; in a badly polluted river, oxygen can be taken first from nitrate and then, with less welcome results, from sulphate, for the oxidation of carbonaceous matter, though not of ammonia. Nitrate in the water may have entered the river in sewage effluents or in surface water draining from agricultural land, or may have been formed in the river by oxidation of ammonia from these sources. Sulphate is found in many hard waters and is a major constituent of sea water.

In an estuary where the water is losing dissolved oxygen in the process of oxidising polluting matter, oxygen is continuously dissolved from the air and also enters in solution from the upper river, tributaries, and the sea, though all of these may carry polluting matter too into the tideway. In addition, microscopic plants in the water, under the influence of sunlight, produce oxygen ; but at other times they abstract it from the water. (Their net effect over the year in the tidal Thames, though doubtful, is thought to be small.) It is obvious that if the oxygen from the sources mentioned is not enough to keep pace with the losses, the proportion of dissolved oxygen will dwindle, but if nitrate is present another process sets in before the oxygen concentration falls to zero. This was already known to workers concerned with river pollution when we were appointed, but the importance of nitrate had not then been thoroughly studied.

It was found by the Laboratory in their work on the Thames that when the dissolved oxygen concentration reaches a low level—somewhat less than 10 per cent of saturation, or under one part per 1,000,000—oxidation of the organic carbon in polluting matter continues at the expense of the oxygen in any nitrate present. The process of reducing nitrate probably does not release much ammonia (which would begin to take up oxygen again as soon as sufficient dissolved oxygen was present) but frees nitrogen, which escapes to the air.

So far as is known, any ammonia carried down from upstream into a zone in which nitrate is being decomposed will pass through it without alteration. The ammonia will be oxidised to nitrate further seawards, but some of the nitrate so formed will be brought back by the tide into the polluted zone and part of it will there yield up its oxygen.

While nitrate is being reduced, bacteria are still using the dissolved oxygen which remains and that which enters through the surface of the water. If readily oxidisable matter is still present when neither nitrate nor dissolved oxygen is left and oxygen from the air is being used as fast as it enters, other bacteria take over the work of decomposition, utilising for the purpose the oxygen in sulphate. The sulphate is reduced to sulphide, which, in the presence of iron salts, is precipitated as black insoluble ferrous sulphide—hence the blackness of the water of which complaint has been made. Excess sulphide remaining in solution is slowly lost to the air as hydrogen sulphide, which is chiefly responsible for the smells complained of and will discolour lead paint and tarnish some metals.

The investigations of the Water Pollution Research Laboratory have shown that sulphide is not found in solution in the Thames estuary in the presence of any significant amounts of either dissolved oxygen or nitrate. It follows that the water will not be in an offensive state if there is always some dissolved oxygen or some nitrate present.

What Further Improvements can Usefully be Made ?

It will be principally due to the presence of nitrate that nuisance is prevented. But nitrate is not in other respects a substitute for dissolved oxygen, which is essential for the survival of fish. In experiments, rainbow trout (a species of the genus to which salmon and sea trout belong) have usually survived in water in which the concentration of dissolved oxygen did not fall below 30 per cent of saturation ; coarse fish can generally tolerate worse conditions. In the dry summers to which the Laboratory predictions relate, the length of river in which there would be enough oxygen to support fish life (in the absence of toxic substances) may be extended a very few miles as a secondary result of schemes costing altogether well over £20,000,000. Heavy expenditure would still be needed to ensure that some dissolved oxygen was always present in all parts of the estuary ; but it is clear that if, for example, 1 or 2 per cent were to be added to the dissolved oxygen content in the worst reaches, little more would have been gained except a substantial insurance against the occurrence of offensive smells. The length of the estuary in which fish cannot live would only have been slightly shortened.

It is obviously desirable that there should be some such insurance. In considering the Laboratory's estimate of the maximum polluting load which the river can take without nuisance arising, allowance should be made not only for errors inherent in the methods of calculation and in the data on which they are based but also for the possible occurrence—rare though it may be—of a prolonged period of flow of less than 170 m.g.d. over Teddington Weir, and for the effects of fluctuations in polluting loads and other factors. However, there is no point in over-insurance, especially when the cost must be reckoned in millions of pounds. In our view, if all that can reasonably be attempted is the avoidance of offensive conditions (and we discuss this below), it would suffice, and it should in the near future be practicable, so to manage the river that the polluting load discharged is smaller by a reasonable fraction—say a quarter—than that which, on calculation, would just avoid the occurrence of sulphide in the water under the adverse conditions of flow and temperature referred to earlier. The exact magnitude of the margin of safety could be reconsidered in a few years' time, when further examination of the estuary will no doubt have eliminated many of the uncertainties which at present make a fairly large safety margin desirable.

Conditions for Fish Migration

Beyond securing this safety margin it appears to us that there is no worthwhile stopping-point short of improving the estuary sufficiently to enable migratory fish, particularly salmon, to pass through it. The conditions which would just allow salmon to pass through the estuary cannot be defined precisely, but the concentration of dissolved oxygen could not be much less than 30 per cent of saturation if the fish were to survive, and a higher oxygen level might well be needed for them to be sufficiently active for migration. It would be necessary also that toxic substances should not be present in the water in concentrations which would kill the fish. The one toxic substance which is known to be present in appreciable quantities is ammonia ; its concentration in recent years has been somewhat lower than that which, we are informed, would have killed salmonid fish in the presence of an oxygen concentration of 50 per cent of saturation. The concentration of ammonia, however, would necessarily be reduced to a fraction of what it now is if steps were taken to raise the dissolved oxygen content of the estuary water to permit the migration of fish, and in those circumstances there would certainly not be enough ammonia to be lethal. So far as is known, there are no considerable quantities of other directly toxic substances in the polluting liquors discharged to the estuary, but these liquors have not been examined with this specific point in view ; they would have to be if the establishment of a fishery were being seriously considered.

For the present, we conclude that there would be some chance of establishing a salmon fishery in the Thames if the polluting load were reduced so as to maintain the dissolved oxygen concentration at about 30 per cent of saturation during April and May in most years, but to be reasonably confident of success we should have to advise an even greater reduction in the polluting load.

The most straightforward way of reducing the polluting load is, no doubt, to purify existing polluting discharges to a greater degree than at present. These measures [eight measures are listed in the report] would be extremely expensive—we are advised that the cost of the further improvements which would be needed at the L.C.C. outfall works alone would exceed £11,000,000, even if the flow treated were not increased as a result of the elimination of stormwater discharges. But expense is not the only difficulty ; a number of the requirements are probably impracticable. For example, the standard of quality which would be required for the Mogden, Acton and Kew sewage effluents is better than has been reliably achieved at any modern disposal works in this country and probably in the world. As for storm water, the quantities discharged could be reduced, at considerable expense, but it is probably even less realistic to-day to think of entirely abolishing storm overflows in London than it was in 1891, when Baker and Binnie regarded the idea as impracticable.

THE ENGINEER

TECHNICAL CONTRIBUTORS SECTION

OCTOBER, 1961

Reciprocating Compressor Factors

By A. J. RICHES B.Sc. (Eng.), M.I.E.E.*

Successful driving of a reciprocating compressor entails more than the mere coupling of a motor rated as specified by the compressor manufacturer. Reciprocating compressors demand an irregular turning effort and different types of driving motor have different inherent characteristics. Motors applied without consideration of the factors involved can result in excessive and unacceptable pulsation of supply current. The order of the current pulsation will depend upon the type of compressor, the constants of the driving motor and the combined inertia of the unit. In general the inertia of the compressor itself is very small so that the bulk must be incorporated in a separate flywheel or in the motor itself in cases where a separate flywheel cannot be used. The problem is how much WR^2 *is required for satisfying a desired current pulsation in any specific case, or what will be the order of the pulsation if the* WR^2 *is known. Reduction of* WR^2 *may make no difference to current pulsation or may even reduce it. The article, illustrated by sixteen diagrams and three photographs, shows how compressor turning effort diagrams may be analysed to give equivalent harmonic torque variations so leading to the production of characteristic* XY *curves from which compressor factors are derived. These Factors, associated with a particular type of compressor and motor constants, define the* WR^2 *required to satisfy a specified degree of current pulsation. An example of the derivation of an* XY *curve is given for a typical compressor and the compressor factors obtained used to calculate current pulsation and* WR^2 *for induction and synchronous motors.*

A COMPRESSOR factor is a figure associated with a particular type of reciprocating compressor, which, in association with given motor constants, defines the order of motor WR^2 required to satisfy a specified degree of current pulsation. Current pulsation is defined as the difference between maximum and minimum current expressed as a fraction or percentage of nameplate rated current. In practice, an oscillograph is used to measure the current pulsation, the order of which is found by dividing the difference between maximum and minimum ordinates of the current envelope by 1·41 times the nameplate rated current. Assuming constant supply pressure and efficiency, variation in watt current is proportional to variation in torque. The torque variation of a compressor is shown by its crank effort or turning moment diagram where the tangential effort on the crankshaft due to the combined gas and inertia forces is plotted on a base of one revolution of the crankshaft, i.e., 360 deg. or 2π radians.

Each type of compressor has a characteristic crank effort diagram for given output conditions depending upon the following main factors :

(*a*) Number and arrangement of cylinders.
(*b*) Whether single- or double-acting.
(*c*) Number of stages.
(*d*) Angular displacement of cranks.
(*e*) Speed, weights of moving parts, ratio of connecting-rod length to crank radius, and clearance volumes.

When a compressor is arranged for operation at partial loads there is a characteristic crank effort diagram for each such load. As is to be expected from the factors involved, the crank effort diagram has an irregular shape, although the pattern may be repeated during a revolution depending upon the number and arrangement of cranks, e.g. a vertical three-crank, single-stage, double-acting compressor with cranks displaced 120 deg. will have the torque variation repeated three times per revolution. The arithmetic mean a_o of the crank effort diagram is the torque corresponding to the indicated horsepower (i.h.p.) at rated speed.

It will be appreciated that the watt current variation cannot be estimated until the irregular shape of the crank effort diagram is replaced by an equivalent form that lends itself to calculation of the desired quantities. This conversion is conveniently accomplished by Fourier analysis, when the shape of the diagram can be expressed by a constant term and a series of harmonics, namely,

$$a_o \pm a_1 \sin \omega t \pm b_1 \cos \omega t \pm a_2 \sin 2\,\omega t \pm b_2 \cos 2\omega t$$
$$\ldots \pm a_n \sin n\,\omega t \pm b_n \cos n\,\omega t$$

where ω is the angular velocity of the crankshaft in mechanical radians per second and n is the order of the harmonic and the higher the value to which it is taken the more closely will the shape approach the original diagram. The sine and cosine term for each harmonic representing torque pulsation about a_o can be combined to give an equivalent sinusoidal quantity q having an amplitude equal to $\sqrt{a^2+b^2}$ and displaced by an angle α equal to $\tan^{-1}b/a$. The four summations depending

TABLE I

Condition	Sine	Cosine	q	α
1	+	+	+	+
2	+	−	+	−
3	−	+	−	−
4	−	−	−	+

The summation for Condition 2 is shown by Fig. 1.

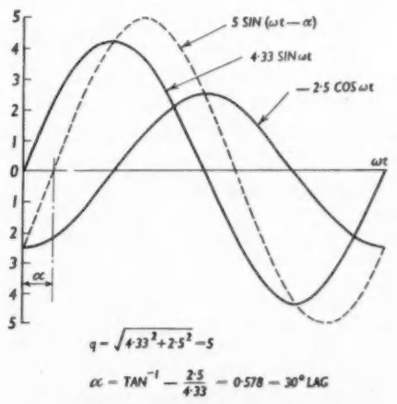


Fig. 1—Summation of $a \sin \omega t - b \cos \omega t$

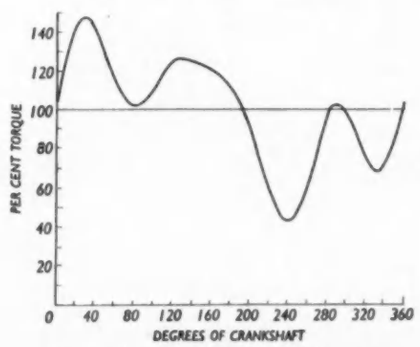


Fig. 2—Compressor crank effort diagram

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Technical Contributors Section *(continued)*

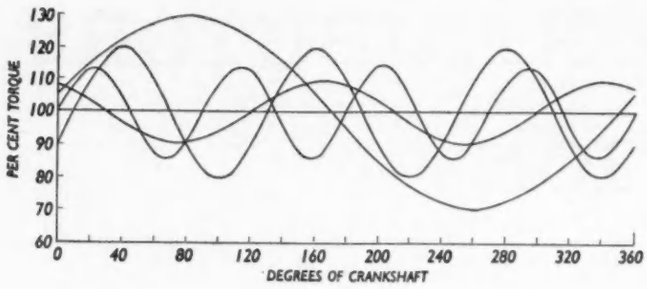

Fig. 3—Fourier analysis of Fig. 2

upon the sign of the sine and cosine terms are as Table I.

Let Fig. 2 be a crank effort diagram as submitted for a particular compressor. From Fourier analysis this diagram can be expressed by $100+30 \sin(\omega t+10) -10 \sin(2\omega t-60) +20 \sin(3\omega t -30) +14 \sin 4\omega t$ where 100 represents the average torque corresponding to indicated horsepower (i.h.p.) and 30, 10, 20 and 14 the amplitudes of the first, second, third and fourth harmonic torques respectively expressed as a percentage of the average torque. These torques are shown by Fig. 3 which when added will reproduce Fig. 2. These torque variations proportional to i.h.p. watt current variations are related to variations in nameplate rated current by a factor Y which is also related to a compressor factor X based upon motor constants thus giving a characteristic XY curve for a particular type of compressor when driven by a given type of motor.

A.C. motors of the induction type or synchronous type are commonly used for driving reciprocating compressors, and occasionally d.c. motors are used. The derivation of XY curves for these types of motor will now be explained.

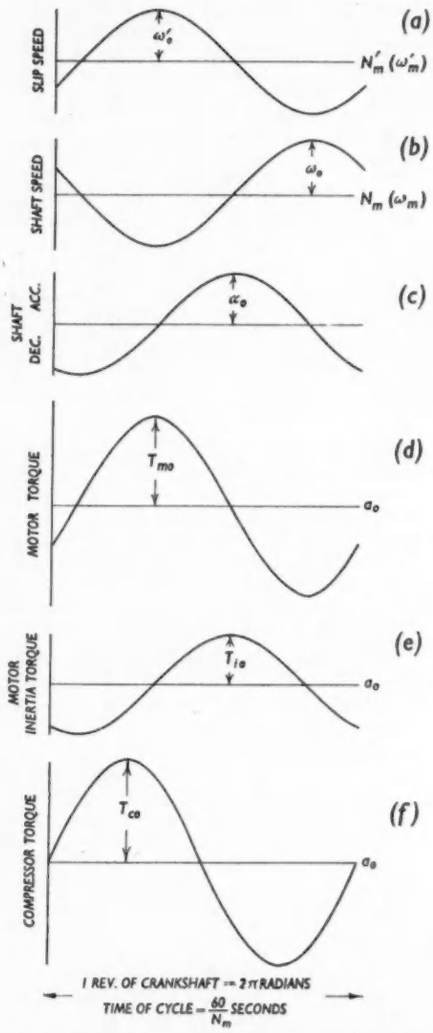

Fig. 4—Induction motor velocity acceleration and torque diagrams

Induction Motors

By definition,

$$\text{slip } S=\frac{N_s-N}{N_s}=\frac{N'}{N_s}$$

and therefore shaft speed $N=(1-S)\,N_s$ where N_s is the synchronous speed, and N' the slip revolutions. The maximum variation of slip ω'_o about the mean slip ω'_m is $\pi/30 \,.\, S_o \,.\, N_s$ mechanical radians per second as shown by Fig. 4 (*a*). The maximum variation of shaft speed ω_o about the mean shaft speed ω_m is also $\pi/30 \,.\, S_o \,.\, N_s$, but is 180 deg. out of phase with the variation of slip as shown by Fig. 4 (*b*). The rate of change of shaft speed α_o is acceleration or deceleration and is the differential of Fig. 4 (*b*) with respect to time as shown by Fig. 4 (*c*). Assuming that over the range of torque variations involved the torque slip characteristic of the motor is a straight line as Fig. 5, then the torque will be, say, K times the slip, and the maximum variation T_{mo} of motor torque about the mean torque T_m is slip $\times K$ or

$$T_{mo}=\frac{30}{\pi}\times\frac{\omega_o'}{N_s}\times K.$$

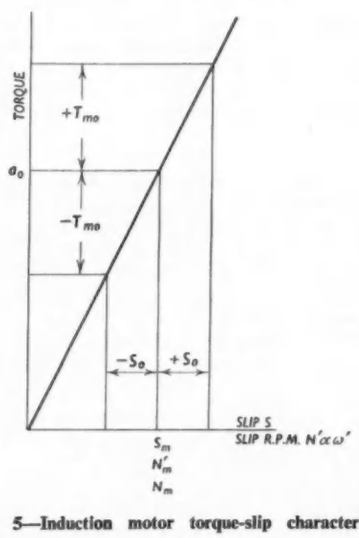

Fig. 5—Induction motor torque-slip characteristic

Torque variation per radian per second of slip variation

$$=\frac{T_{mo}}{\omega_o'}=\frac{30\times K}{\pi\times N_s}=\text{say } B.$$

The motor torque must supply the compressor torque and its own inertia torque, or at any instant $T_{mo}=T_{co}+T_{io}$.

The motor torque $B\omega_o'$ is in phase with ω_o' as shown in Fig. 4 (*d*), while the inertia torque Ia_o of the motor is in phase with a_o as shown in Fig. 4 (*e*). The sum of Fig. 4 (*e*) and 4 (*f*) therefore gives the motor torque in Fig. 4 (*d*).

The magnitude and displacement of the torques shown graphically in Fig. 4 can also be determined mathematically.

$$T_{mo}=T_{co}\sin\omega t+T_{io}$$

$$T_{mo}-T_{io}=T_{co}\sin\omega t$$

$$=B\omega_o'-I\frac{d\omega_o}{dt}=T_{co}\sin\omega t$$

$$=B\omega_o'+I\frac{d\omega_o'}{dt}=T_{co}\sin\omega t$$

The solution of which is

$$\omega_o'=\frac{T_{co}\sin(\omega t-\delta)}{\sqrt{B^2+(\omega I)^2}}$$

where

$$\delta=\tan^{-1}\frac{\omega I}{B}$$

It will be observed that the form of the equation is the same as that for an electrical circuit comprising resistance and inductance

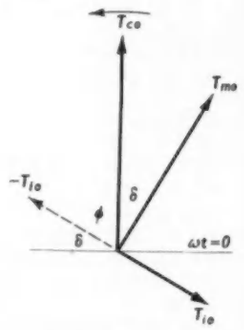

Fig. 6—Vector representation of torques in Fig. 4

in series when $Ri+L\,di/dt=E\sin\omega t$. The solution of this is the well known

$$i=\frac{E\sin(\omega t-\phi)}{\sqrt{R^2+(\omega L)^2}}=\frac{E\sin(\omega t-\phi)}{Z}$$

where ϕ is the angle of lag, the cosine of which is the power factor and equal to R/Z.

Motor torque

$$T_{mo}=B\omega_o'=\frac{B\times T_{co}}{\sqrt{B^2+(\omega I)^2}}\times\sin(\omega t-\delta)$$

Inertia torque

$$T_{io}=-I\frac{d\omega_o'}{dt}=-\frac{\omega I\times T_{co}}{\sqrt{B^2+(\omega I)^2}}\times\cos(\omega t-\delta)$$

$$=-\frac{\omega I\times T_{co}}{\sqrt{B^2+(\omega I)^2}}\times\sin(\omega t+\phi)$$

where

$$\phi=\tan^{-1}\frac{B}{\omega I}$$

The former plus the latter gives the compressor torque and is shown vectorially by Fig. 6 for the instant when T_{co} is a maximum, i.e. $\omega t = 90$ deg. $= \pi/2$ radians. Figs. 4 and 6 are therefore different forms of representation of the torque relationships.

Replacing T_{co} sin ωt by $\sqrt{a^2+b^2}$ sin $(\omega t \pm \alpha)$ as shown in the introduction. T_{mo} becomes

$$\frac{B\times\sqrt{a^2+b^2}}{\sqrt{B^2+(\omega I)^2}}\times \sin(\omega t \pm \alpha - \delta)$$

Taking n harmonics into account and generalising

$$\sum T_{mo_n} = \sum \frac{B\times\sqrt{a_n^2+b_n^2}}{\sqrt{B^2+n^2(\omega I)^2}} \sin(n\omega t \pm \alpha_n - \delta_n)$$

Dividing both sides by the mean torque a_o

$$\sum \frac{T_{mo_n}}{a_o} = \sum \frac{\sqrt{A_n^2+B_n^2}}{\sqrt{1+n^2\left(\frac{\omega I}{B}\right)^2}} \sin(n\omega t \pm \alpha_n - \delta n)$$

where

$$A_n = \frac{a_n}{a_o} \text{ and } B_n = \frac{b_n}{a_o}$$

$\sum \frac{T_{mo_n}}{a_o}$ is the torque pulsation as a fraction of the average torque of the theoretical diagram.

Assuming linear relationships between watt current and torque the fractional watt current pulsation is proportional to the fractional torque pulsation.

Let

$$\sum \frac{T_{mo_n}}{a_o} \text{ be equal to } Y,$$

then the per cent watt current pulsation on a basis of i.h.p. is $100Y$ or on a b.h.p. basis is $100Y\times$ i.h.p./b.h.p., assuming no change in speed.

Assuming constant power factor over the torque pulsation, the per cent pulsation of the nameplate rated current is $100Y\times$ i.h.p./b.h.p. and Y per cent = b.h.p./i.h.p. $\times$ per cent current pulsation

Y is also equal to

$$\sum \frac{\sqrt{A_n^2+B_n^2}}{\sqrt{1+n^2\left(\frac{\omega I}{B}\right)^2}} \times \sin(n\omega t \pm \alpha_n - \delta_n)$$

$$= \sum \frac{\sqrt{A_n^2+B_n^2}}{\sqrt{1+n^2Z^2}} \times \sin(n\omega t \pm \alpha_n - \delta_n)$$

where

$$Z = \frac{\omega I}{B}$$

Substituting for

$$\omega = \frac{\pi \times N_m}{30}$$

where N_m is the r.p.m. corresponding to i.h.p.

$$I = \frac{WR^2}{g}$$

$$K = \frac{\text{b.h.p.}\times 5250}{S_{FL}\times N_{FL}}$$

where N_{FL} is the r.p.m. corresponding to b.h.p. and

$$B = \frac{30\times K}{\pi \times N_S}$$

and S_{FL} is the fractional slip corresponding to b.h.p. gives

$$Z = \frac{WR^2\times N_M\times N_S\times S_{FL}\times N_{FL}}{15{\cdot}4\times 10^6\times \text{b.h.p.}}$$

For all practical purposes N_m is equal to N_{FL} and substituting for $N_{FL} = N_S(1-S_{FL})$ gives

$$Z = \frac{WR^2\times N_S^3\times(1-S_{FL})^2\times S_{FL}}{15{\cdot}4\times 10^6\times \text{b.h.p.}}$$

The value of S_{FL} will depend upon the b.h.p. and synchronous speed of the motor involved, the curves in Fig. 7 being typical values for normal 50 cycle 3300V slipring motors. Cage motors may differ appreciably depending upon whether the rotors are of the normal or high-slip type. In the reduction of the expression no great error will be introduced by assuming an average value for S_{FL} for substitution only in the expression for $(1-S_{FL})$. Assuming an average value to be 0·03 and substituting gives

$$Z = \frac{WR^2\times N_S^3\times S_{FL}}{16{\cdot}5\times 10^6\times \text{b.h.p.}}$$

Substituting $\overline{N_s}$ as the synchronous speed per 1000 revolutions per minute and adopting $\overline{S_{FL}}$ as the percentage slip at rated b.h.p. output gives

$$Z = \frac{WR^2\times(\overline{N_S})^3\times\overline{S_{FL}}}{1{\cdot}65\times \text{b.h.p.}}$$

Putting $Z\times 1{\cdot}65 = X$, the compressor factor, gives

$$X = \frac{WR^2\times(\overline{N_S})^3\times\overline{S_{FL}}}{\text{b.h.p.}}$$

where WR^2 is in lb-ft^2 units. The expressions developed may now be used to calculate the XY curve for any given compressor.

Taking as an example the case of a two-stage double-acting horizontal compressor with 90 deg. cranks and requiring an i.h.p. of 435 at 244 r.p.m. and to be driven by a slipring induction motor rated at 550 b.h.p. at 243 r.p.m. on a three-phase, 50 cycle, 3300V supply. From the harmonic analysis of the crank effort diagram, evaluate

$$Q_n = \sqrt{A_n^2+B_n^2} \text{ and } \alpha_n = \tan^{-1}\frac{B_n}{A_n}$$

for a number of harmonics, usually not greater than six, and tabulate as Table II to determine the numerator of Y. Assume a value of Z and for the same number of harmonics considered in Table II evaluate the denominator of Y and hence Y itself together with the appropriate displacement angle and tabulate as Table III. Draw the resulting sine curves as Fig. 8 and by inspection determine the maximum heights above and below the datum line and add together to give a value of Y for the chosen value of Z and plot on a base of $X = 1{\cdot}65\ Z$. For completeness the resultant summation is shown in its entirety in Fig. 8. This procedure is repeated for a number of values for Z sufficient to give an XY curve to cover the values of Y likely to be required. Taking the ratio of b.h.p. to i.h.p. to be 1·2 then Y will be 72 for a nameplate current pulsation of 60 per cent.

The calculation and plotting of the many curves involved is a lengthy and tiring task, but set up as a programme on a digital computer the time taken to obtain the points on an XY curve becomes only a matter of minutes. Fig. 9 is the complete XY curve as given by an English Electric "DEUCE" computer for the example selected. From this it will be noticed that the value of Y equal to 69 corresponding to $X = 0{\cdot}82$ ($Z = 0{\cdot}5$) is in close agreement with the figure obtained by the actual calculation and plotting in Tables II and III and Fig. 8.

A standard 24 pole, 50 cycle, 3300V slipring induction motor rated at 550 b.h.p. to B.S.2613/1957 class "A" insulation would have a WR^2 of the order of 6·0 tons-ft^2 and a full load slip of about 3·0 per cent. Fig. 9

TABLE II—a_o = 9442 lbs ft

Harmonic	1	2	3	4	5	6
a	+2850	− 585	+1887	+1363	+ 176	− 95
b	+ 425	+ 663	−1120	− 166	− 371	+ 574
A	+ 30·2	− 6·2	+ 20·0	+ 14·5	+ 1·86	− 1·0
B	+ 4·5	+ 7·0	− 11·9	− 1·76	− 3·94	+ 6·1
$Q = \sqrt{A^2+B^2}$	+ 30·6	− 9·3	+ 23·2	+ 14·60	+ 4·35	− 6·15
tan $\alpha = B/A$	0·15	1·13	0·60	0·12	2·12	6·10
α (deg.)	9	48	31	7	65	81
Condition No. (Table I)	1	3	2	2	2	3

TABLE III

$$C = \frac{1}{\sqrt{(nZ)^2+1}} \quad \tan\delta = nZ$$

$Z = 0{\cdot}5$ ($X = 0{\cdot}82$)

n	nZ	$(nZ)^2+1$	C	$Q\times C$	δ	Displacement angle	Curve (Fig. 8)
1	0·5	1·25	0·895	27·4	27	+ 9−27 = − 18	*A*
2	1·0	2·00	0·707	−6·6	45	−48−45 = − 93	*B*
3	1·5	3·25	0·555	12·9	56	−31−56 = − 87	*C*
4	2·0	5·00	0·446	6·5	64	− 7−64 = − 71	*D*
5	2·5	7·25	0·372	1·6	68	−65−68 = −133	*E*
6	3·0	10·00	0·316	−1·95	72	−81−72 = −153	*F*

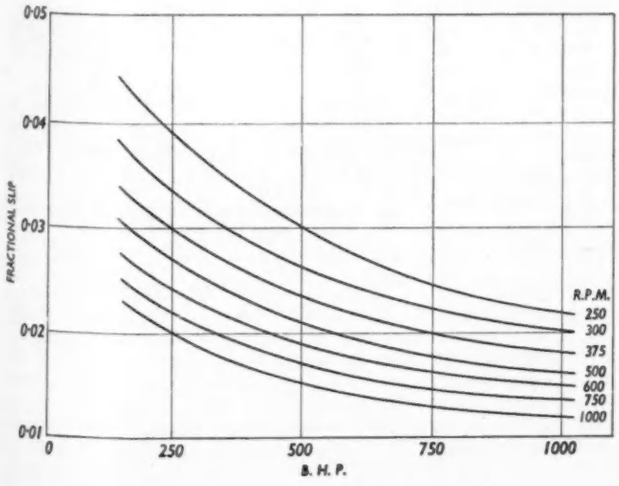

Fig. 7—H.P.-slip curves for typical 50-cycle 3300V slipring motors

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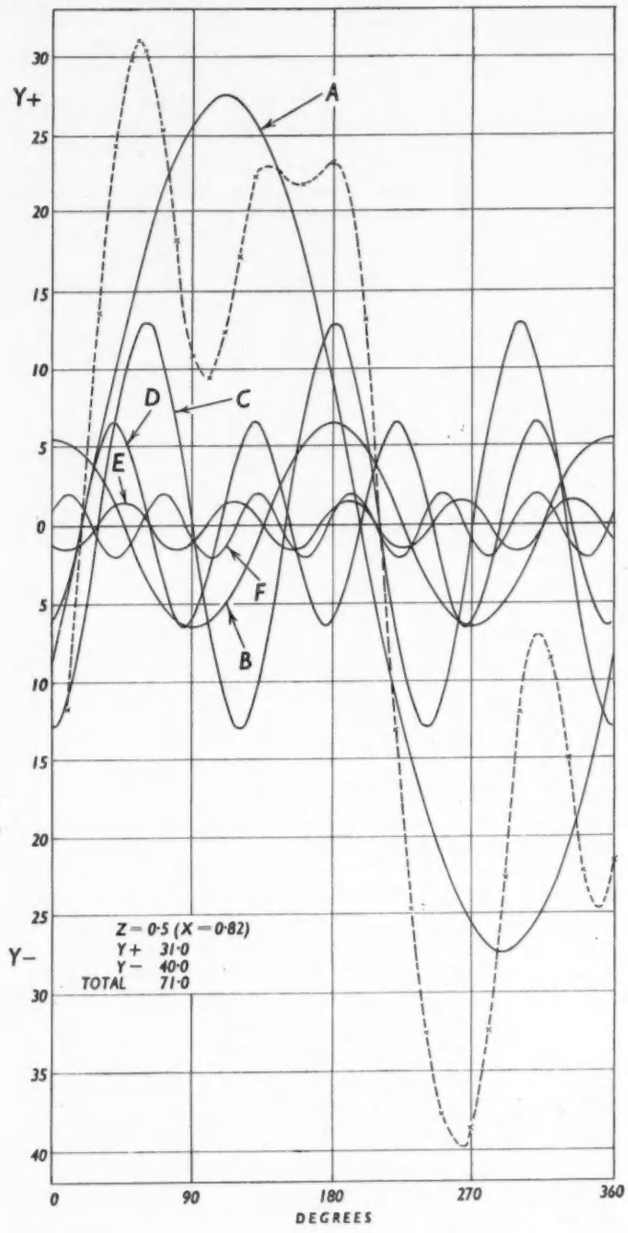

Fig. 8—Harmonic torques from Table III

can now be used to find the current pulsation.

$$X=\frac{6\cdot0\times2240\times(0\cdot25)^3\times3\cdot0}{550}=1\cdot14$$

From Fig. 9 the corresponding value of Y is 58 and equal to b.h.p./i.h.p. × per cent *C.P.* from which

$$\text{per cent } C.P.=\frac{58\times435}{550}$$

or 46·0 per cent of nameplate current. Suppose the desired per cent *C.P.* to be 30 per cent then Y would be

$$\frac{550}{435}\times30=38\cdot0$$

giving $X=2\cdot30$.

The product of WR^2 (tons-ft²) and per cent slip is

$$\frac{2\cdot3\times550}{(0\cdot25)^3\times2240}=36\cdot2$$

Retaining a standard electrical design requires the provision of a total WR^2 of 12·0 tons-ft². With a single- or two-bearing motor there is no difficulty since additional WR^2 over the motor WR^2 of 6·0 tons-ft² can be incorporated in a separate flywheel mounted between motor and compressor. In cases where a separate flywheel cannot be accommodated as shown in Figs. 10 and 11 additional WR^2 would have to be met by the adoption of a rotor of increased diameter having a flywheel type hub which may or may not yield all the required additional WR^2, any deficiency in WR^2 having to be offset by increased slip resulting in a lowered efficiency.

It will be appreciated that in certain cases the attainment of a specified current pulsation may only be achieved by a compromise between price and efficiency and requests for unreasonable low orders of current pulsation are not in the best interests of manufacturer and purchaser. Over-rating of the motor b.h.p. by adding " contingencies " will result in optimistic current pulsation.

D.C. Motors

The procedure for obtaining XY curves for induction motors driving reciprocating compressors is equally applicable to d.c. motors when used as an alternative form of drive providing there is a linear, or sensibly linear, relationship between torque and speed drop over the torque variations involved. Slip will have the same meaning as for induction motors but in the expression for X, N_s will have to be replaced by N_{NL}, the no-load speed of the d.c. motor. Hence for d.c. motors

$$X=\frac{WR^2\times(N_{NL})^3\times S_{FL}}{\text{b.h.p.}}$$

where N_{NL} is the no load speed per 1000 revolutions per minute.

Y remains unchanged equal to b.h.p./i.h.p. × per cent current pulsation.

Synchronous Motors

Loading a synchronous motor results in an angular displacement between the supply voltage and the axis of the poles. The angle σ known as the load angle is, for a salient-pole synchronous motor, equal to

$$\tan^{-1}\frac{IX_q\cos\phi}{V+IX_q\sin\phi}$$

derived from the vector diagram based upon the two-axis theory where

I = Per unit load current

X_q = Per unit quadrature axis synchronous reactance

V = Per unit terminal voltage

ϕ = Power factor angle

For non-salient-pole motors, i.e. synchronous induction motors with a cylindrical rotor having a distributed field winding X_q is replaced by X_s the synchronous reactance.

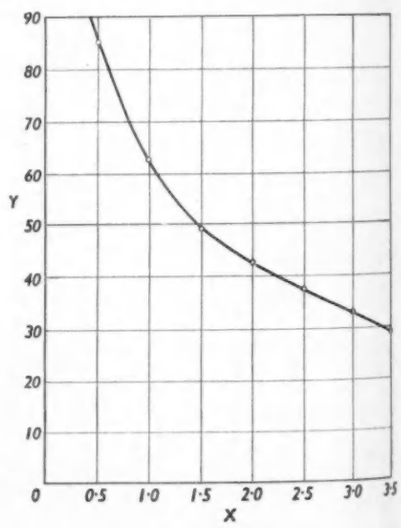

Fig. 9—*XY* curve for induction-motor-driven compressor in worked example

There is a relationship between power (or torque) and the load angle which, although not strictly linear over the working range of the motor, may from experience, however, be so regarded for predicting synchronous motor operation when driving reciprocating compressors. This factor, known as the synchronising coefficient P_r, is defined as the shaft power divided by the load angle, and

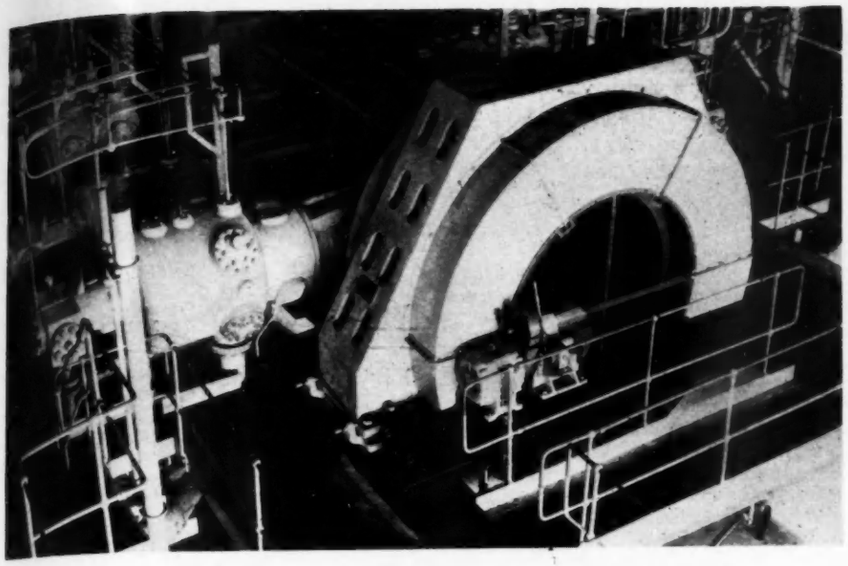

Fig. 10—Overhung cage-type motor driving gas compressor at a chemical works

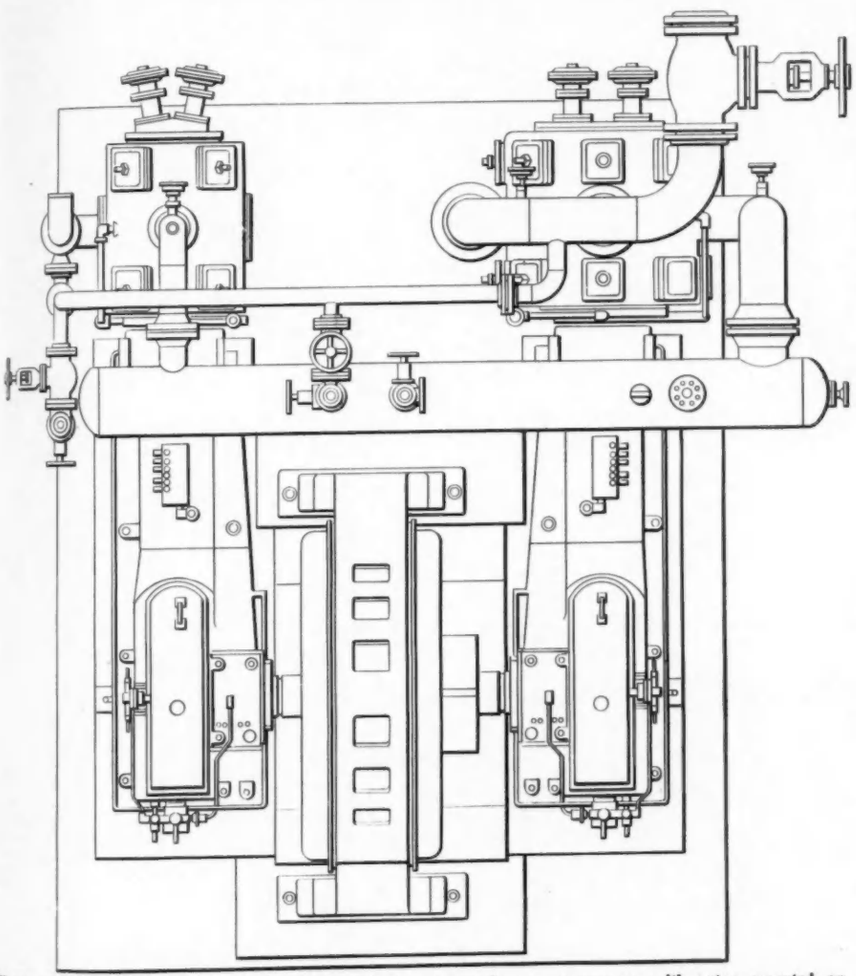

Fig. 11—Arrangement of two-cylinder horizontal type ammonia gas compressor with rotor mounted on crankshaft

is expressed as kilowatts per electrical radian. For the purpose of the following analysis this factor will be referred to as the synchronising torque coefficient T_s and expressed as lb-ft per mechanical radian displacement. In addition to the synchronising torque *S.T.* there are two other torques : damping and inertia torques. The damping torque *D.T.*, much smaller than *S.T.*, is proportional to the angular velocity or rate of change of angular displacement, and its coefficient T_d is expressed as lb-ft per mechanical radian per second of displacement. Increase of load increases the displacement angle and the rotor falls backwards from its previous position, thereby increasing the damping torque in the same way that an induction motor produces an increase of torque with an increase of slip. The inertia torque *I.T.* is equal to the product of the rotor mass moment of inertia and the rate of change of angular velocity (acceleration or deceleration.) A falling back of the rotor is equivalent to deceleration or negative acceleration.

The motor torques must supply the compressor torque *C.T.* and its own acceleration torque hence

$$S.T.+D.T.=C.T.+(-I.T.)$$

or

$$S.T.+D.T.+I.T.=C.T.$$

The synchronising, damping and inertia torques combine as shown in Fig. 12 and 14 depending upon whether the synchronising torque is greater or less than the inertia torque. Conditions when $S.T.>I.T.$ are shown in Fig. 12 in which (*a*) is the displacement angle either side of the load angle, (*b*) is the angular velocity, i.e., the differential with respect to time of (*a*), and (*c*) is the rate of change of angular velocity, i.e. the differential with respect to time of (*b*). The synchronising torque is in phase with (*a*) and is shown in (*d*). The inertia torque is in phase with (*c*) and is shown in (*e*) with the resultant of (*d*) and (*e*) shown in (*f*). The damping torque is in phase with (*b*) and shown in (*g*). The resultant of *S.T.*, *I.T.* and *D.T.* is the compressor torque *C.T.* shown in (*h*).

Conditions when $I.T.>S.T.$ are shown by Fig. 14 with the three torques still in phase with their appropriate quantities (*a*), (*b*) or (*c*) which quantities have the same meaning as Fig. 12. In Fig. 14 *S.T.* and *I.T.* have changed to (*e*) and (*d*) and (*f*) is the resultant of *I.T.* and *S.T.* The damping torque is still (*g*) and the three torques thus combine in a different manner from Fig. 12 to give the compressor torque in Fig. 14 (*h*). The magnitude and phase displacements of the torques can be seen by vectorial representation of the conditions where Fig. 13 corresponds to Fig. 12 and Fig. 15 to Fig. 14.

As with the induction motor, conditions may also be determined mathematically. Let ψ be the mechanical radians displacement from the steady load angle, then

$$\text{Synchronising torque } S.T.=T_s\times\psi$$

$$\text{Damping torque } \quad D.T.=T_d\times\frac{d\psi}{dt}$$

$$\text{Inertia torque } \quad I.T.=I\times\frac{d^2\psi}{dt^2}$$

Since only variations about the mean torque a_o of the theoretical compressor torque are being considered then

$$I\frac{d^2\psi}{dt^2}+T_d\frac{d\psi}{dt}+T_s\psi=T_{co}\sin\omega t$$

the solution of which is

$$\psi=\frac{T_{co}\sin(\omega t-\delta)}{\sqrt{(T_s-I\omega^2)^2+\omega^2T_d^2}}$$

where

$$\tan\delta=\frac{\omega Td}{T_s-I\omega^2}$$

hence

$$S.T.=\frac{T_s\times T_{co}}{\sqrt{(T_s-I\omega^2)^2+\omega^2T_d^2}}\times\sin(\omega t-\delta)$$

$$D.T.=\frac{\omega T_d\times T_{co}}{\sqrt{(T_s-I\omega^2)^2+\omega^2\ T_d^2}}\times\sin(\omega t+\phi)$$

where

$$\tan\phi=\frac{T_s-I\omega^2}{\omega T_d}$$

and

$$I.T.=-\frac{I\omega^2\times T_{co}}{\sqrt{(T_s-I\omega^2)^2+\omega^2T_d^2}}\times\sin(\omega t-\delta)$$

from which it will be seen that the torques and their phase angles agree with the graphical and vectorial representations in Figs. 12 and 13 respectively.

Technical Contributors Section (*continued*)

When

$$I\omega^2 > T_s \text{ or } I.T. > S.T. \text{ then}$$

$$\psi = -\frac{T_{co}\sin(\omega t+\delta)}{\sqrt{(I\omega^2-T_s)^2+\omega^2T_d^2}}$$

where

$$\tan\delta = \frac{\omega T_d}{I\omega^2-T_s}$$

giving

$$S.T. = -\frac{T_s\times T_{co}}{\sqrt{(I\omega^2-T_s)^2+\omega^2T_d^2}}\times\sin(\omega t+\delta)$$

$$D.T. = \frac{\omega T_d\times T_{co}}{\sqrt{(I\omega^2-T_s)^2+\omega^2T_d^2}}\times\sin(\omega t-\phi)$$

where

$$\tan\phi = \frac{I\omega^2-T_s}{\omega T_d}$$

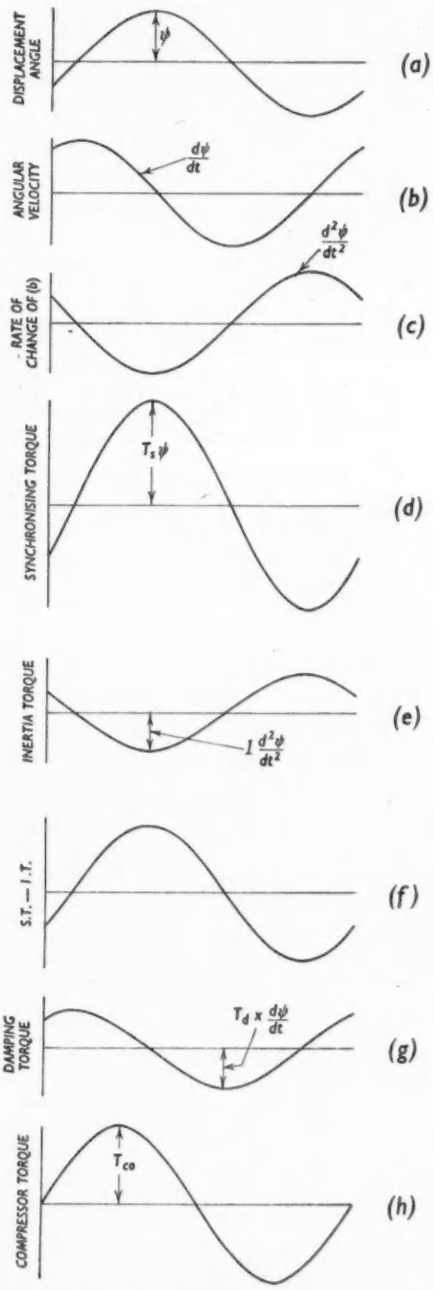

Fig. 12—Synchronous motor displacement, velocity, acceleration and torque diagrams when *S.T.*>*I.T.*

and

$$I.T. = \frac{I\omega^2\times T_{co}}{\sqrt{(I\omega^2-T_s)^2+\omega^2T_d^2}}\times\sin(\omega t+\delta)$$

and again the torques and displacements agree with Figs. 14 and 15.

In the induction motor case the mechanical system was similar to an electrical series resistance-reactance circuit. With the synchronous motor the mechanical system is similar to an electrical series resistance-reactance-capacitance circuit, Figs. 12 and 13 corresponding to the case when the capacitance is greater than the reactance. If V_R, V_C and V_L are the respective voltages across the resistor, capacitor and reactor then V_C is similar to *S.T.*, V_L to *I.T.* and V_R to *D.T.* with the maximum of the supply pressure E similar to T_{co}. Figs. 14 and 15 correspond to the case when the reactance is greater than the capacitance.

Neglecting damping, resonance will occur when $I\omega^2=T_s$, or $\omega=\sqrt{T_s/I}$ and the natural frequency

$$f_n = \frac{1}{2\pi}\sqrt{\frac{T_s}{I}}$$

and hence when $T_s>I\omega^2$ the disturbing (forcing, exciting) frequency $f_d<f_n$. Conversely when $I\omega^2>T_s$ then $f_d>f_n$.

Replacing $T_{co}\sin\omega t$ by a combination of a $\sin\omega t$ and $b\cos\omega t$ as in the induction motor case then

$$\psi = \frac{\sqrt{a^2+b^2}}{\sqrt{(T_s-I\omega^2)^2+\omega^2T_d^2}}\sin(\omega t\pm\alpha+\delta)$$

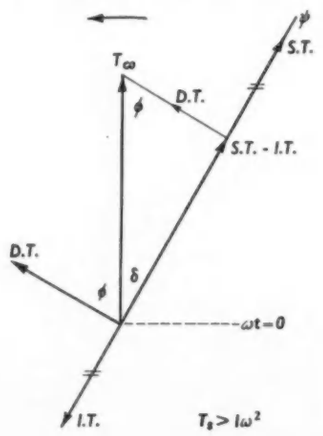

Fig. 13—Vector representation of torques in Fig. 12

where as previously ωt is now reckoned from the origin of the sine and cosine base.

Taking n harmonics into account and generalising

$$\sum\psi_n = \sum\frac{\sqrt{a_n^2+b_n^2}}{\sqrt{(T_s-I\omega^2n^2)^2+n^2\omega^2T_d^2}}\times\sin(n\omega t\pm\alpha_n\pm\delta_n)$$

$$\tan\alpha_n = \frac{b_n}{a_n}$$

$$\tan\delta_n = \frac{n\omega T_d}{T_s-n^2\omega^2I}$$

†Neglecting the damping torque compared with the synchronising torque and assuming the motor torque is the synchronising torque alone, then multiplying both sides by T_s/a_o gives :

† Including the damping torque with the synchronising torque, the expression for Y is as shown in the Appendix. Taking the order of λ for the appropriate harmonic into account the slight difference in the expressions does not justify the refinement.

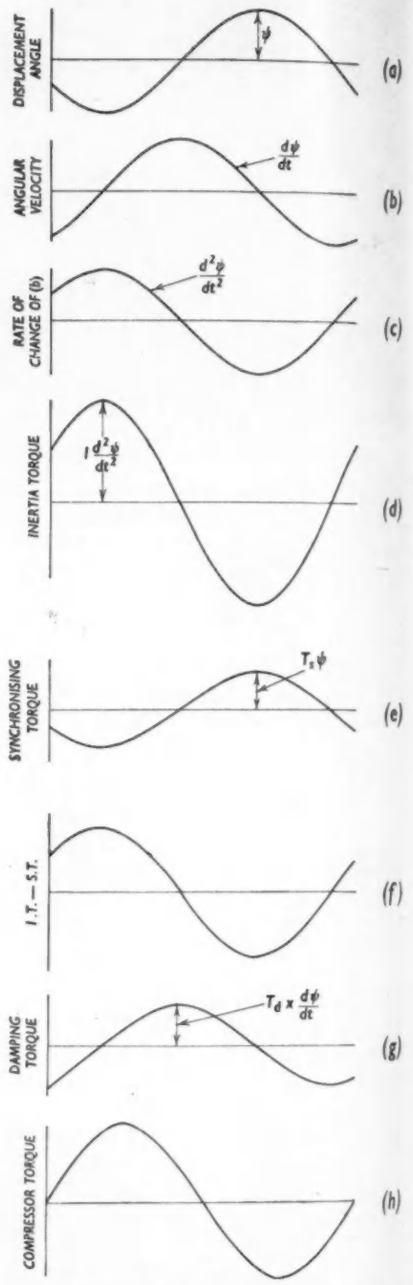

Fig. 14—Synchronous motor displacement, velocity, acceleration and torque diagrams when *I.T.*>*S.T.*

$$\sum\frac{\psi_n\times T_s}{a_o} = \sum\frac{\sqrt{\left(\frac{a_n}{a_o}\right)^2+\left(\frac{b_n}{a_o}\right)^2}}{\sqrt{\left(1-\omega^2n^2\frac{I}{T_s}\right)^2+\omega^2n^2\left(\frac{T_d}{T_s}\right)^2}}\times\sin(n\omega t\pm\alpha_n\pm\delta_n)$$

$$= \sum\frac{\sqrt{A_n^2+B_n^2}}{\sqrt{\left(1-\omega^2n^2\frac{I}{T_s}\right)^2+\omega^2n^2\left(\frac{T_d}{T_s}\right)^2}}\times\sin(n\omega t\pm\alpha_n\pm\delta_n)$$

where $A_n=\frac{a_n}{a_o}$

and $B_n=\frac{b_n}{a_o}$

Let

$$\sum\frac{\psi_n\times T_s}{a_o}$$

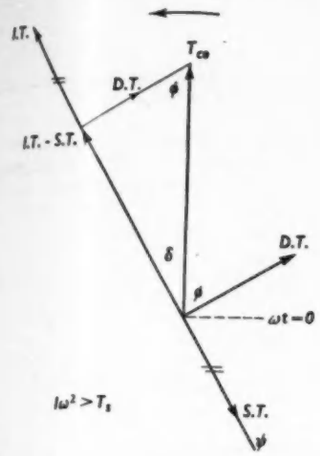

Fig. 15—Vector representation of torques in Fig. 14

which is the torque pulsation as a fraction of the average torque of the theoretical diagram, be equal to Y. Since the motor speed is practically constant Y is also the fractional power or watt current pulsation based upon the i.h.p. Assuming constant power factor over the torque pulsation, the percentage pulsation of the nameplate rated current is therefore

$$Y \times \frac{\text{i.h.p.}}{\text{b.h.p.}}$$

and

$$Y \text{ per cent} = \frac{\text{b.h.p.}}{\text{i.h.p.}} \times \text{per cent current pulsation}$$

Putting

$$Z = \frac{I\omega^2}{T_s} \text{ and } \lambda = \frac{\omega T_d}{T_s}$$

then

$$Y = \sum_{o} \frac{\psi_n \times T_s}{} = \sum \frac{\sqrt{A_n^2 + B_n^2}}{\sqrt{1-n^2Z)^2 + n^2\lambda^2}} \times \sin(n\omega t \pm \alpha_n \pm \delta_n)$$

$$\tan \alpha_n = \frac{B_n}{A_n}$$

$$\tan \delta_n = \frac{n\lambda}{(1-n^2Z)}$$

λ is not constant but varies with speed and the order of harmonic. Experience has shown that no appreciable error is introduced if λ is taken as a constant and equal to 0·1.

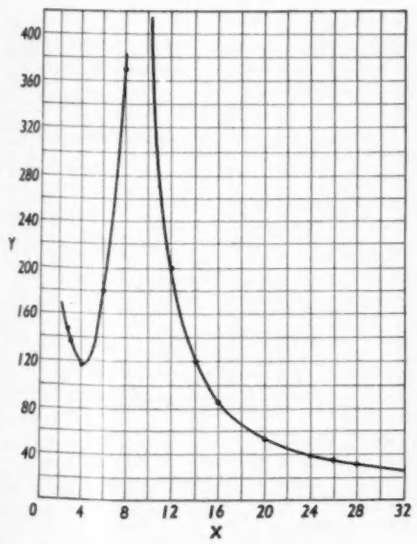

Fig. 16—XY curve for synchronous-motor-driven compressor in worked example

With σ equal to the load angle in electrical degress then

$$\frac{\sigma \times 2\pi}{360}$$

is the load angle in electrical radians, and

$$\frac{\sigma \times 2\pi \times 2}{360 \times \text{poles}}$$

is the load angle in mechanical radians or

$$\frac{\sigma \times 2\pi \times N_s}{360 \times 60 \times \sim}$$

where $\sim$ is the supply system frequency.

Neglecting damping

$$f_n = \frac{1}{2\pi}\sqrt{\frac{T_s}{I}}$$

$$= \frac{1}{2\pi}\sqrt{\frac{\text{Torque per mech. radian}}{I}}$$

$$= \frac{1}{2\pi}\sqrt{\frac{\text{kW}}{\cdot 746} \times \frac{33{,}000}{2\pi \,.\, N_s} \times \frac{360 \times 60 \times \sim}{\sigma \times 2\pi \times N_s \times I}}$$

Substituting

$$P_r = \text{kW/elec. rad.} = \frac{\text{kW} \times 360}{\sigma \times 2\pi}$$

gives

$$f_n = \frac{587}{N_s}\sqrt{\frac{P_r \times \sim}{WR^2}} \text{ c/s or } \frac{35{,}200}{N_s}\sqrt{\frac{P_r \times \sim}{WR^2}} \text{ c/m}$$

$$Z = \frac{I\omega^2}{T_s} = \left(\frac{\omega}{\sqrt{\frac{T_s}{I}}}\right)^2$$

$$= \left(\frac{2\pi N_s}{60 \times 2\pi f_n}\right)^2 \text{ and } f_n^2 = \left(\frac{N_s}{60}\right)^2 \times \frac{1}{Z}$$

hence

$$\frac{587^2}{N_s^2} \times \sqrt{\frac{P_r \times \sim}{WR^2}} = \left(\frac{N_s}{60}\right)^2 \times \frac{1}{Z}$$

from which

$$Z = \frac{N_s^4 \times WR^2}{12{\cdot}4 \times 10^8 \times P_r \times \sim}$$

putting $12{\cdot}4Z = X$ the compressor factor gives

$$X = \frac{N_s^4 \times WR^2}{P_r \times \sim \times 10^8}$$

Putting $9{\cdot}25Z = C$ the compressor factor as defined in American Standard C.50.1 1955 (Section 1.11.3.3.) gives

$$C = \frac{0{\cdot}746 \times N_s^4 \times WR^2}{P_r \times \sim \times 10^8}$$

where

$$C = X = 9{\cdot}25Z$$

The natural frequency in c/m has been shown to be

$$\frac{35{,}200}{N_s} \times \sqrt{\frac{P_r \times \sim}{WR^2}}$$

and eliminating P_r, $\sim$ and WR^2 from the above two expressions gives

$$f_n = \frac{3{\cdot}04 \times N_s}{\sqrt{C}}$$

To avoid the resonance zone it is usual to keep the natural frequency to below $0{\cdot}8\ N_s$ or above $1{\cdot}25\ N_s$. It will be seen that a value for C to satisfy a specified order of current pulsation may or may not be acceptable from a natural frequency standpoint.

The XY curve may now be calculated in a similar manner to that used for induction motors. Taking the same compressor used in the induction motor example the harmonic analysis in Table II still applies, but a new table, a section of which is given in Table IV, is required for the evaluation of the denominator of Y and also Y itself together with the appropriate displacement angle. Following previous procedure, the various curves for a given value of $Z(X)$ are evaluated to establish the value for Y. Further values for Z are chosen sufficient to give an XY curve to cover practical values. Fig. 16 is the complete

TABLE IV

$$C = \frac{1}{\sqrt{(1-n^2Z)^2 + (0{\cdot}1n)^2}} \qquad \tan\delta = \frac{n\lambda}{(1-n^2Z)}$$

$Z = 0{\cdot}5$ ($X = 4{\cdot}63$)

n	$(1-n^2Z)$	$n\lambda$	C	Q×C	δ	Displacement angle
1… … … … … … … … …	0·5	0·1	1·96	60·0	11	+9−11 = − 2
2… … … … … … … … …	− 1·0	0·2	0·98	−9·1	11	−48+11−180= −217
3… … … … … … … … …	− 3·5	0·3	0·285	6·6	5	−31+ 5−180= −206
4… … … … … … … … …	− 7·0	0·4	0·143	2·1	3	− 7+ 3−180= −184
5… … … … … … … … …	−11·5	0·5	0·087	0·38	2	−65+ 2−180= −243
6… … … … … … … … …	−17·0	0·6	0·059	−0·36	2	−81+ 2−180= −259

Note:
(1) When $(1-n^2Z)$ is negative, i.e. $I\omega^2 > Ts$ the displacement angle is $-(\omega t + \delta)$, i.e. $\omega t + \delta - 180$.
(2) In the above table n is taken to 6. Usually n up to 4 is sufficient unless there is a pronounced harmonic and multiples

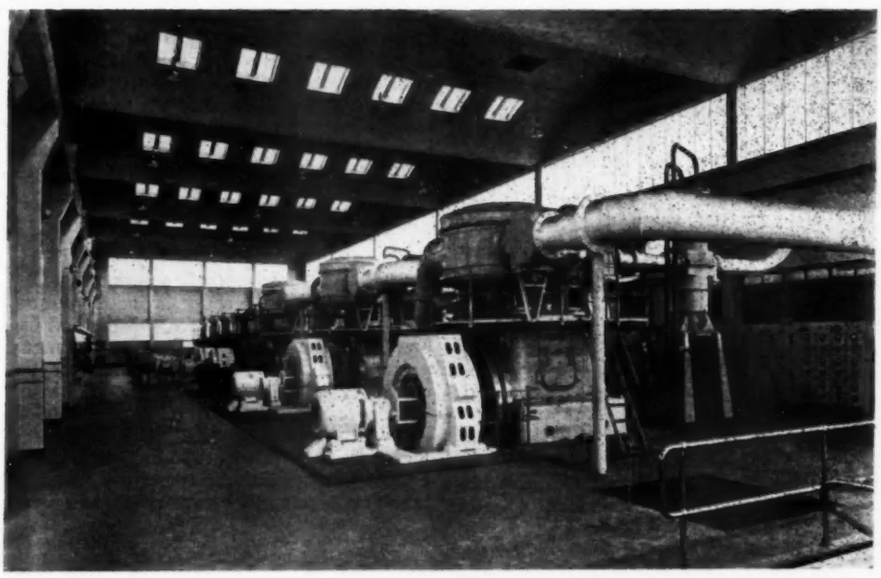

Fig. 17—Synchronous-motor-driven air compressors at a colliery

Technical Contributors Section (*continued*)

XY curve plotted from figures given by an English Electric "DEUCE" computer.

With $N_s=250$ r.p.m. and $a_o=9442$ lb-ft the i.h.p. is 450.

Suppose the motor is to be rated at 570 b.h.p. Unity power factor class "A" Insulation B.S.2613/1957 on a three-phase, 50 cycle, 3300V supply.

A standard motor would have a P_r of about 1070 and a WR^2 of approximately 6·0 tons ft² giving

$$C=X=\frac{0\cdot746\times250^4\times6\times2240}{1070\times50\times10^6}=7\cdot3$$

and

$$f_n=\frac{3\cdot04\times250}{\sqrt{7\cdot3}}=282 \text{ c/min}$$

This frequency is too near the running frequency and must be lowered to round about 200 or raised to about 300.

Taking an accepted current pulsation of 66 per cent,

$$Y=\frac{570}{450}\times66=84$$

corresponding to $X=C$ on Fig. 16 of 16·0 whence f_n becomes

$$\frac{3\cdot04\times250}{\sqrt{16}}=190 \text{ c/min}$$

which is acceptable.

Although P_r can be adjusted to a limited extent the attainment of $X=16$ can only be achieved by increase of WR^2 from standard 6·0 ft² to 12/13 tons ft². If the motor is to be of the single- or two-bearing type as shown in Fig. 17, the additional WR^2 can be embodied in a flywheel and a standard motor adopted. If, however, the motor is to be of the overhung type, a form which is gaining popularity, then the whole of the necessary WR^2 must be incorporated in the motor rotor. To obtain twice the normal WR^2 will mean an increase in frame bore, in order to take advantage of R^2, and also the adoption of a "flywheel rim." Such a motor would have a P_r of the order of 980 which together with a WR^2 of 12·0 tons ft² would yield the required C of 16, but at the expense of 12½/15 per cent increase in cost over a standard motor and a slightly less efficient machine.

Figs. 18 and 19 are XY curves for two further types of compressor and in conjunction with Fig. 16 all have widely differing characteristics. Fig. 18 applies to a three-cylinder, single-stage, double-acting compressor with cranks at 120 deg. In this case no difficulty arises with current pulsation due to the low values of X compared with Y. Fig. 19 is for a twin two-stage, single-acting compressor having two horizontally opposed pistons per stage with the h.p. stage leading the l.p. stage by 90 deg. In this instance, provided the natural frequency is acceptable, two values of X will satisfy a Y of 50 or a limited range of low values of X and a single higher value of X when Y is above 50. The choice of X, from the point of economy, is in the low range and would be selected whenever possible. Specification of a current pulsation that required Y less than 50 leaves no choice but a more expensive motor. On the other hand an existing system WR^2 giving $X=12$ could be reduced to ½ to ½ of its WR^2 without any change in percentage current pulsation.

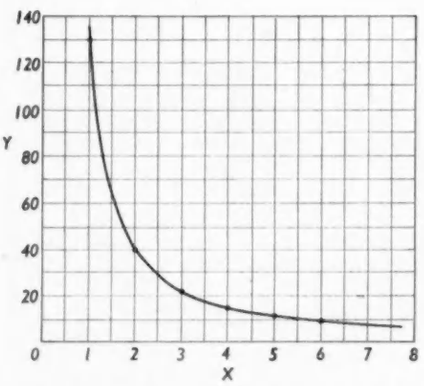

Fig. 18—XY curves for synchronous-motor-driven three-cylinder single-stage double-acting compressor with cranks at 120 deg.

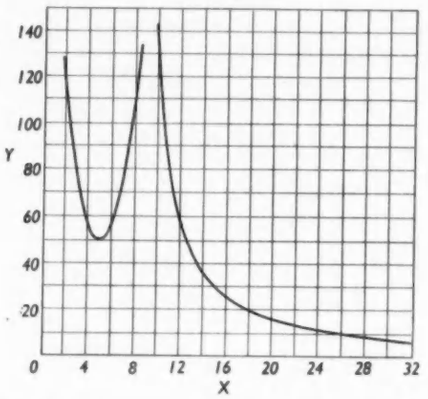

Fig. 19—XY curves for synchronous-motor-driven twin two-stage single-acting compressor with two horizontally opposed pistons per stage

The remarks in the induction motor section concerning low orders of current pulsation and "contingencies" apply equally to synchronous motors. It will be appreciated that current pulsation must be separately investigated for each type of compressor, together with the form of driving motor to be employed.

Depending upon the manufacturer of a particular type of compressor for a given output and speed there will be some differences in their theoretical torque diagrams. Despite such differences it is possible to classify the various types and tabulate their compressor factors for various orders of current pulsation. Such a table for Synchronous Motor Compressor Application Factors is Appendix 1.11.3 of ASA.C.1.1955.

Conclusions

While the method of determining XY curves, especially for synchronous motors, cannot be regarded as exact, this method has been used for this class of motor for many years in the U.S.A. and is the accepted approach to the subject, experience having shown that results are in close practical agreement with prediction. It is hoped that the adoption of this method by British motor and compressor manufacturers will lead to a better understanding between them and users.

Acknowledgment

The author is indebted to the English Electric Company, Ltd. for permission to publish this article and for facilities afforded for its preparation, and to his colleagues for their assistance and cooperation.

APPENDIX

$$\psi=\frac{T_{co}\sin(\omega t-\delta)}{\sqrt{P^2+Q^2}} \qquad P=T_s-\omega^2 I \qquad Q=\omega T_d \tan\delta=\frac{Q}{P}$$

$$\frac{d\psi}{dt}=\frac{\omega T_{co}\cos(\omega t-\delta)}{\sqrt{P^2+Q^2}}$$

$$S.T.+D.T.=T_s\psi+T_d\frac{d\psi}{dt}$$

$$=\frac{T_{co}}{\sqrt{P^2+Q^2}}[T_s\sin(\omega t-\delta)+\omega T_d\cos(\omega t-\delta)]$$

$$=\frac{T_{co}}{\sqrt{P^2+Q^2}}\left[\sqrt{T_s^2+\omega^2T_d^2}\sin(\omega t-\delta+\gamma)\right]$$

$$\tan\gamma=\frac{\omega T_d}{T_s}$$

$$=\frac{T_{co}}{\sqrt{P^2+Q^2}}\left[\sqrt{T_s^2+\omega^2T_d^2}\sin(\omega t-\beta)\right]$$

$$\beta=(\delta-\gamma)$$

Replacing $T_{co}\sin\omega t$ by $\pm a\sin\omega t\ \pm b\cos\omega t$ equal to $\sqrt{a^2+b^2}\sin(\omega t\pm\alpha)$ where $\tan\alpha=b/a$ then

$$S.T.+D.T.=\frac{\sqrt{a^2+b^2}}{\sqrt{P^2+Q^2}}\left[\sqrt{T_s^2+\omega^2T_d^2}\sin(\omega t\pm\alpha-\beta)\right]$$

Total motor torque at i.h.p.

$$\frac{a_0}{}=\frac{\sqrt{\left(\frac{a}{a_o}\right)^2+\left(\frac{b}{a_o}\right)^2}\times T_s\times\sqrt{1+\frac{\omega^2T_d^2}{T_s^2}}}{\sqrt{(T_s-\omega^2I)^2+\omega^2T_d^2}}\sin(\omega t\pm\alpha-\beta)$$

$$=\frac{Q\times\sqrt{1+\frac{\omega^2T_d^2}{T_s^2}}}{\sqrt{\left(1-\frac{\omega^2I}{T_s}\right)^2+\left(\frac{\omega T_d}{T_s}\right)^2}}\sin(\omega t\pm\alpha-\beta)$$

Taking n harmonics into account and generalising

$$\sum\frac{\text{Total motor torque at i.h.p.}}{a_0}$$

$$=\sum\frac{Q_n\times\sqrt{1+n^2\left(\frac{\omega T_d}{T_s}\right)^2}}{\sqrt{\left(1-\frac{n^2\omega^2I}{T_s}\right)^2+n^2\left(\frac{\omega T_d}{T_s}\right)^2}}\sin(n\omega t\pm\alpha_n-\beta_n)$$

With $Z=I\omega^2/T_s$ and $\lambda=\omega T_d/T_s$ the torque pulsation as a fraction of the torque corresponding to i.h.p. is

$$\sum\frac{Q_n\times\sqrt{1+n^2\lambda^2}}{\sqrt{(1-n^2Z)^2+(n\lambda)^2}}\sin(n\omega t\pm\alpha_n-\beta_n)$$

where

$$\tan\alpha_n=\frac{b_n}{a_n}$$

$$\tan\delta_n=\frac{n\omega T_d}{T_s-n^2\omega^2I}=\frac{n\lambda}{1-n^2Z}$$

$$\tan\gamma_n=\frac{n\omega T_d}{T_s}=n\lambda$$

$$\beta_n=\delta_n-\gamma_n=\tan^{-1}\frac{n\lambda}{1-n^2Z}-\tan^{-1}n\lambda$$

References

Part of the material for the synchronous motor section of this article is based upon the following papers published by The American Society of Mechanical Engineers.

Paper APM-51-12, "Calculation of Flywheels for Air Compressors," by H. R. Goss and H. V. Putman, 1929.

Paper 56-F-18, "Calculating the Size of Flywheel Required for a Synchronous Motor-driven Reciprocating Compressor," by M. N. Halberg, 1956.

A Discrepancy of Indication

By G. WALKER* and F. A. PLUMB*

A number of tests have been carried out with the object of comparing the indicator diagrams obtained by two engine indicators. One of the indicators was of conventional form, with lightweight moving parts and using a tapered cantilever spring instead of the usual compression coil spring. The other indicator was a Farnboro using a spark control system developed at B.I.C.E.R.A. The experiments were carried out on a single-acting four stroke cycle single-cylinder gas/oil engine. Diagrams were obtained over the speed range 800 to 1300 r.p.m. and at B.M.E.P's ranging from 60 to 110 lb per inch, with the engine operating on both gas and oil. The rates of pressure change during combustion with operations on gas were well outside the recommended limit for the mechanical indicator. High frequency oscillation note on the indicator diagram under these conditions are attributed to indicator spring oscillation, gas pressure pulses in the indicator passage or pressure waves due to detonation in the cylinder. Substantial differences were observed between the maximum pressure and indicated mean effective pressure measured by the two indicators.

RECIPROCATING piston type mechanical indicators are not generally used on machines operating in excess of 800 r.p.m. With increasing speed the significance of the errors inherent in such a system become appreciable and tend to make the diagram obtained valueless as a record of the pressure changes in the system. In addition to the speed limitation there is a further restriction in the rate of pressure change to which the piston and linkage system is able to respond satisfactorily. These effects have long been recognised.

A High Speed Mechanical Indicator

Among the many indicating devices available for use with engines of moderate speed there is one mechanical type, made by H. Maihak A.G., which is claimed "to permit perfect records to be obtained at speeds up to 2400 r.p.m. and pressure change rates exceeding 20,000 atmospheres per second."

This indicator is shown in section in Fig. 1. It is similar to conventional forms but in place of a coil spring to control the piston motion a tapered cantilever spring is used. All the moving parts are exceptionally light in weight, but the fixed platform is of robust construction. At high speeds it is not possible to connect the indicator drum drive directly to the engine and it becomes necessary to use one of two special devices supplied as auxiliaries to the indicator. One of these, the automatic friction clutch, is shown in Fig. 2, coupled to the indicator. This unit consists, essentially, of a crank connecting rod system coupled by means of a friction clutch, to a shaft driven by the engine at crankshaft speed. The crank connecting rod system is used to reproduce the motion of the piston in the test engine. The ratio of the crank and connecting rod length is infinitely variable in the range from 1 : 3·5 and 1 : 5.

The upper end of the connecting rod, reciprocating in a crosshead, is coupled to the indicator drum by a light steel tape. Guide rolls are used to change the direction of the tape as required. The clutch is manually engaged and disengaged. It is designed so that the initial drive is taken by a friction clutch and this is followed by the engagement of a spring loaded dog clutch to ensure that the driven shaft is synchronised with the engine shaft. A feature of the clutch is that the drum drive may be engaged in any position, in 30 deg. increments, relative to the engine crankshaft. This is particularly useful for work on multicylinder engines since diagrams can be taken from all cylinders without stopping the engine. The diagrams are correctly phased relative to the engine crankshaft, providing that the engine cranks are dispersed at 30 deg., 60 deg., and 90 deg. increments. A further advantage of this phasing adjustment is that diagrams from any particular cylinder can be taken 90 deg. out of phase. Thus the period when combustion is taking place in the engine cylinder is "spread" over the centre portion of the diagram. Waxed cards 4·5in by 1·4in are used on the drum and the diagrams are themselves limited in size to about 2in long and 1in high.

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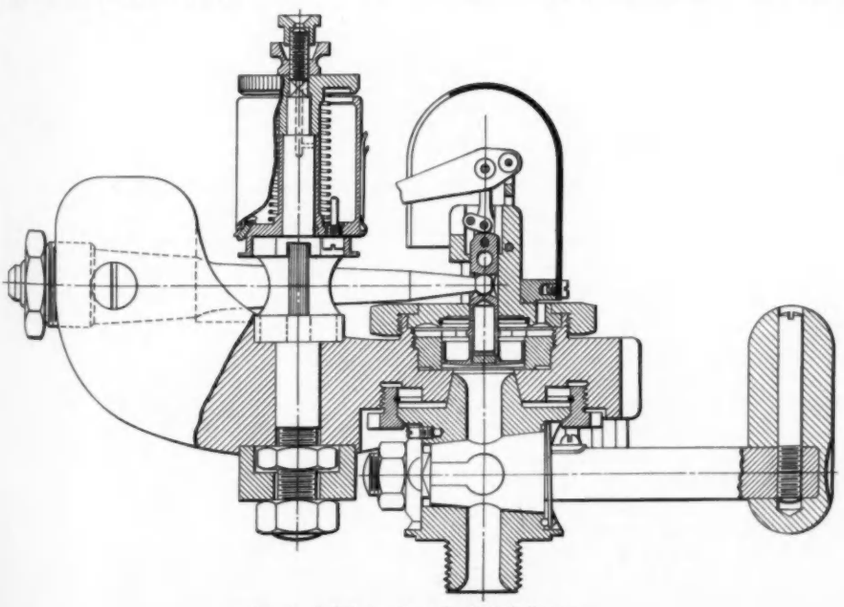

Fig. 1—High-speed mechanical indicator

Other Types of Indicator

Other types of indicator available for use with high speed engines may be classified into :

(*a*) Indicators which make use of a C.R.O. to display the signal obtained from a transducer located in or near the engine cylinder.

(*b*) The balanced pressure electro-mechanical indicator of which the Farnboro is the earliest and best known example. This consists essentially of a drum driven by the engine and a stylus which moves adacent to and parallel to the axis of the drum. The position of the stylus is controlled by a piston in a cylinder acted upon by a controlled gas pressure and restrained by two calibrated tension springs. The same gas pressure acting on the piston is also applied to one side of a diaphragm in the transducer mounted in or near the engine cylinder. The engine cylinder pressure acts on the other side of the diaphragm. When the two pressures are about the same the diaphragm moves and this movement can be used to trigger off a high voltage spark from the stylus to the drum. The spark perforates the diagram paper wrapped around the drum and the spark hole then fixes one point on the pressure-crank angle diagram. Various systems may be used to translate the motion of the diaphragm into a high-voltage spark. One system due to Mansfield and Cornish[1] makes use of a Standard Sunbury disc value pressure transducer. This produces a small electromotive force which is induced by the movement of a very light disc in a magnetic field when the two pressures are about equal. After amplification the signal is applied to the grid of a thyratron valve which releases pulses of current into the primary winding of a high tension coil thereby generating the high voltage spark.

Comparative Tests

Both the indicators discussed above are susceptible to various errors and it was thought to be interesting to carry out some comparative tests with the object of establishing the degree of co-relation existing between the diagrams measured by the two instruments. An important difference is that the mechanical indicator records single cycle phenomena while the Farnboro is composed from several hundred cycles thus giving an average diagram.

The Test Engine

The engine used for the tests was a single-cylinder single-acting four stroke cycle National gas/oil engine of 4·125in bore with a 6in stroke, a compression ratio of 15 : 1 with a rated output of 10 b.h.p. at 1000 r.p.m. This engine was selected because of the fact that it was equipped to operate on oil, gas or any intermediate mixture of the two fuels. It was known that when operating with gas as the fuel the rate of pressure change during

[1] Mansfield, W. P., and Cornish, A. H., 1951. B.I.C.E.R.A. Report No. 51/S, "Methods Used at the B.I.C.E.R.A. Laboratory for Obtaining Pressure Diagrams."

Technical Contributors Section (*continued*)

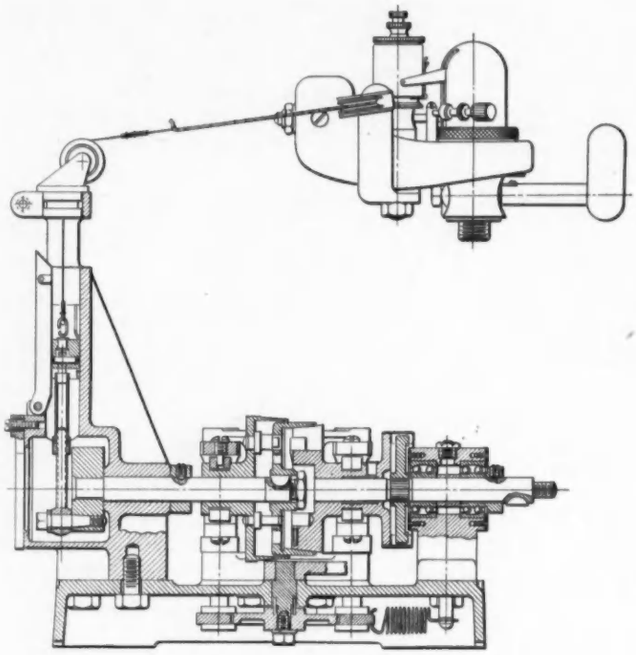

Fig 2 — High-speed indicator connected to clutch coupling device

combustion was very much higher than the corresponding rate of pressure change with oil as the fuel. Thus it appeared possible to separate the two effects of (*a*) engine speed and (*b*) the maximum rate of pressure change in the engine cylinder. It was thought that any desired rate of pressure change during combustion between the two limits could be achieved by careful regulation of the oil, gas and air supply. The engine was controlled by constant speed governing gear adjustable over the range 800 to 1300 r.p.m. A single tapped hole drilled through the cylinder head was provided for indicating purposes. The initial tests were carried out with a "T" adaptor screwed into this hole and carrying both the pressure pickup of the Farnboro and the cock of the mechanical indicator. In a later series of tests another hole was drilled through the cylinder head so that the mechanical indicator and the pressure pickup of the Farnboro could be mounted separately and directly in the cylinder head. The object of providing this second hole was to reduce the length of the indicator passage and to avoid changes in direction and cross section of the passage. The second hole was arranged to enter the cylinder at the same radial and angular inclination as the original existing hole and was made the same diameter.

Range of Tests

Diagrams were taken from both indicators with the engine operating over the speed range 800 to 1300 r.p.m. and at B.M.E.P.'s ranging from 60 to 110 lb per square inch for both gas and oil operation. Very rich gas mixtures were used but, even so, detonation was thought to occur during most of the tests with gas as the fuel.

At any particular operating condition the engine was allowed to attain a steady state and then diagrams were taken. In some cases diagrams were taken simultaneously from both indicators. In other cases diagrams from the mechanical indicator were taken before and after the diagrams from the Farnboro. Because of a mechanical failure of the engine it was not possible to carry out a really comprehensive test programme.

Test Results

In all cases there was a considerable difference in the diagrams returned by the two indicators. In Fig. 3 the two diagrams obtained with the engine running on oil at 800 r.p.m. are shown. In Fig. 4 a comparison is made between the two pressure/volume diagrams for this case drawn to the same scale and superimposed. It is characteristic of most of the diagrams obtained when running on oil as the fuel.

In Table I a comparison is made between the maximum pressure and the indicated mean effective pressure for a range of load and speed conditions with the engine operating on oil as the fuel.

In Table II a similar comparison is made with the engine operating on gas as the fuel.

The rates of pressure change listed in the tables are the maximum rates as estimated from the pressure/crank-angle diagram of the

Table I.—*Indicator Comparison Tests for Operation on Oil*

Speed r.p.m.	Maximum rate of pressure change (atmospheres per second)	Mean effective pressure, lb per square inch		Maximum pressure, lb per square inch	
		Mechanical Indicator	Farnboro	Mechanical Indicator	Farnboro
800	14,250	122·5	131	820	998
900	15,100	127·5	135	800	964
1000	14,400	131·5	149	770	927
1100	14,800	139·2	162	740	893
1200	13,650	143·5	165	650	827
1300	12,900	151	171	620	812

Table II.—*Indicator Comparison Tests for Operation on Gas*

Speed r.p.m.	Maximum rate of pressure change (atmospheres per second)	Mean effective pressure, lb per square inch		Maximum pressure, lb. per square inch	
		Mechanical Indicator	Farnboro	Mechanical Indicator	Farnboro
1000	144,000	135	139	970	995
1100	144,000	144	149	950	975
1200	144,000	148	154	900	965
1300	144,000	157	163	850	960

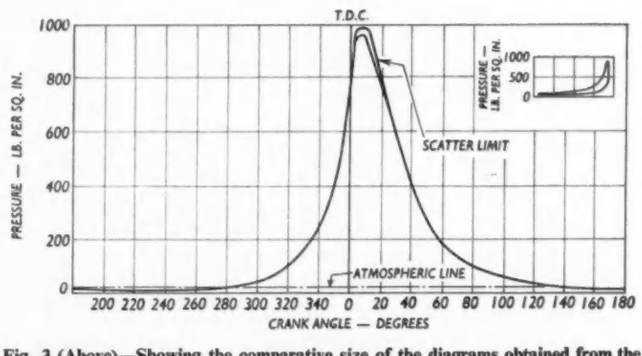

Fig. 3 (Above)—Showing the comparative size of the diagrams obtained from the two indicators with the engine operating on oil fuel at a speed of 800 r.p.m.

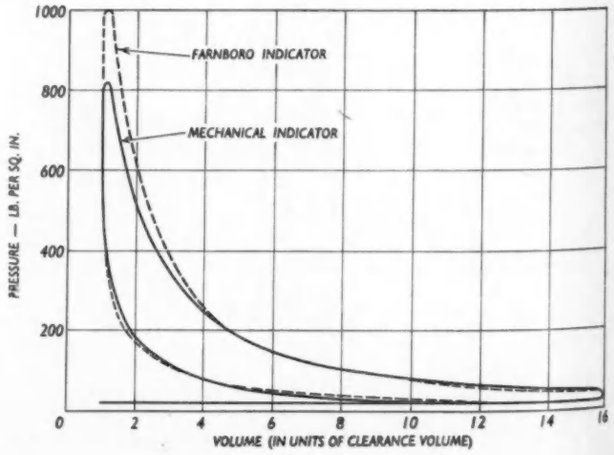

Fig. 4 (Right)—Superimposed work diagrams derived from indicator diagrams obtained with the engine operating on oil fuel at a speed of 800 r.p.m.

Farnboro indicator. It is difficult to be precise in this estimation and these values should be treated as very approximate. It is probably true, however, that the maximum rate of pressure change in the engine cylinder when operating on gas as the fuel was increased by a factor of about 10 compared to the corresponding rate operating on oil.

When operating on gas the maximum rate of pressure change was estimated at about 140,000 atmospheres per second as compared with the manufacturer's recommended maximum rate of 20,000 atmospheres per second. It is interesting to note, however, that under these extreme conditions the correlation between the maximum and mean effective pressures, as measured by the two indicators, is fairly good. When operating on oil, with maximum rates of pressure change quite moderate at 14,000 atmospheres per second, the correlation is only about 85 per cent. All the indicator diagrams measured during operations on gas showed severe pressure oscillations during the expansion stroke. The frequency of these oscillations was approximately constant over the speed considered and so probably arose out of oscillations of the cantilever spring or gas pressure pulses in the indicator passage. Therefore the results for operations with gas with these extremely high rates of pressure change should be largely discounted. The good correlation obtained was probably a fortuitous combination of error.

The length of the diagram returned by the mechanical indicator was observed to increase with speed from 1·81in at 800 r.p.m. to 1·84in at 1300 r.p.m. This effect is thought to be due to "whipping" of the steel tape or to the increased inertia effect of the drum at the higher speed.

Conclusions

The number of tests carried out were insufficient to establish any substantial amount of data but it does appear that different results can be obtained from different indicators used on the same engine under the same conditions. It is difficult to explain how the Farnboro indicator could show higher pressures than those reached in the engine. It is not difficult to see how friction effects could cause the mechanical indicator to record lower maximum pressures than actually attained.

Acknowledgments

The authors wish to acknowledge the assistance of Professor A. F. Burstall, Director of the Stephenson Engineering Laboratories, Kings College, Newcastle upon Tyne, in the provision of experimental facilities.

Accelerating a Rotor through a Critical Speed

By FRANCIS HOWITT*

Theoretical and experimental analyses provide a guide to the design and safe operation of rotors passing through a critical speed.

MANY machines operate above their minimum critical speed and considerable effort has been devoted to the accurate determination of these speeds for various systems. Surprisingly little interest, however, has been shown in what happens to a rotor as it passes *through* a critical speed, although it is obviously of great importance if the amplitude of whirl is to be kept to a minimum.

The basic theory of whirling is that of Jeffcott[1] who has shown that the motion of the elastic centre of a light shaft carrying a mass M at the centre of its span, eccentric a distance ε from the elastic centre, can be described by the equations :

$$M\frac{d^2}{dt^2}(x+\varepsilon\cos\theta)+R\frac{dx}{dt}+Kx=0 \quad . \quad (1)$$

and

$$M\frac{d^2}{dt^2}(y+\varepsilon\sin\theta)+R\frac{dy}{dt}+Ky=0 \quad . \quad (2)$$

where x and y are the co-ordinates of the elastic centre, θ is the angle between the x-axis and the line joining the elastic centre to the centre of mass, R is the coefficient of damping due to viscous resistance and K is the shaft stiffness.

These equations describe the motion of the elastic centre under any conditions ; thus if the shaft rotates with a constant angular velocity ω, then at time t, $\theta=\omega t$ and the equations become :

$$M\frac{d^2}{dt^2}(x+\varepsilon\cos\omega t)+R\frac{dx}{dt}+Kx=0$$

and

$$M\frac{d^2}{dt^2}(y+\varepsilon\sin\omega t)+R\frac{dy}{dt}+Ky=0$$

which simplify to the well-known form :

$$M\frac{d^2x}{dt^2}+R\frac{dx}{dt}+Kx=M\varepsilon\omega^2\cos\omega t \quad . \quad (3)$$

and

$$M\frac{d^2y}{dt^2}+R\frac{dy}{dt}+Ky=M\varepsilon\omega^2\sin\omega t \quad . \quad (4)$$

Now consider the same system accelerating smoothly from rest at a rate $\dot{\omega}$; in this case $\theta=\frac{\dot{\omega}t^2}{2}$ and Equations (1) and (2) become :

$$M\frac{d^2}{dt^2}\left(x+\varepsilon\cos\frac{\dot{\omega}t^2}{2}\right)+R\frac{dx}{dt}+Kx=0$$

and

$$M\frac{d^2}{dt^2}\left(y+\varepsilon\sin\frac{\dot{\omega}t^2}{2}\right)+R\frac{dy}{dt}+Ky=0$$

Differentiating the terms in brackets :

$$M\frac{d^2x}{dt^2}+R\frac{dx}{dt}+Kx=M\varepsilon\left[\dot{\omega}^2t^2\cos\frac{\dot{\omega}t^2}{2}+\dot{\omega}\sin\frac{\dot{\omega}t^2}{2}\right] \quad . \quad . \quad . \quad (5)$$

and

$$M\frac{d^2y}{dt^2}+R\frac{dy}{dt}+Ky=M\varepsilon\left[\dot{\omega}^2t^2\sin\frac{\dot{\omega}t^2}{2}-\dot{\omega}\cos\frac{\dot{\omega}t^2}{2}\right] \quad . \quad . \quad . \quad (6)$$

Unfortunately, unlike Equations (3) and (4), no simple solutions exist to this latter pair.

A possible approach, however, is indicated by Lewis[2] who has solved the equation . . .

$$\frac{W}{g}\ddot{x}+d\dot{x}+kx=P\cos(\pi ht^2+\sigma)$$

where W, g, d, k, P, h and σ are all constants, and x and t are the variables ($\ddot{x}$ and $\dot{x}$ being the second and first derivatives respectively of x with respect to t). Lewis claimed that this equation described the motion of a machine subjected to uniform acceleration; in fact this is incorrect since the amplitude of the disturbance as well as the frequency increases with time and the exciting force should, therefore, have been not

$$P\cos(\pi ht^2+\sigma)$$

but

$$P[(2\pi ht)^2\cos(\pi ht^2+\sigma)+2\pi h\sin(\pi ht^2+\sigma)],$$

as has just been shown. Nevertheless the paper is important because it does demonstrate a most ingenious method of integrating the terms encountered in the solution of Equations (5) and (6).

The latter operation involves considerable labour and produces extremely complex results ; however, their ability to reproduce the graphical solutions to the same equations obtained by Baker[3], using a differential analyser, provide a ready, although equally laborous means of verification. The next step is to simplify the solutions by successive approximations until the relative importance of the various constants can be assessed.

Interest is mainly limited to the maximum amplitude of whirl experienced and since the transient vibrations due to initial conditions will be negligible by the time the critical speed is attained these terms may be eliminated. Other terms too will be relatively small at the critical speed and if an accuracy of only 10 per cent is demanded, then considerable simplification is possible, particularly if account is taken of the fact that the damping in systems is relatively small compared with the rotor stiffness.

By such means it may be shown that the maximum amplitude of whirl of a rotating shaft . . .

$$r_{max}\doteqdot\varepsilon\sqrt{4\frac{K}{M}-\left(\frac{R}{M}\right)^2}\left(k_1+\sqrt{\frac{k_2}{\dot{\omega}}}\right)$$

where

ε=eccentricity of the centre of mass from the elastic centre.
M=rotor mass.
K=rotor stiffness.
R=rotor damping.
$\dot{\omega}$=angular acceleration.
k_1 and k_2 are constants

$\left(\text{at low accelerations}\quad k_1<<\sqrt{\frac{k_2}{\dot{\omega}}}\right)$.

Inspection of the above formula reveals that the maximum amplitude of whirl may be reduced by increasing the angular acceleration and that the effect is greatest at low accelerations. Acceleration is no substitute for good balancing, however, since the amplitude under any conditions is directly proportional to the mass eccentricity. Increasing the stiffness of a rotor system raises the critical speed, with a consequent increase in the unbalance forces at that speed giving a greater amplitude. Increasing the damping has the reverse effect since it reduces the speed of response of the system to the unbalance forces : even with no damping, however, the maximum amplitude will be finite provided the system is accelerating (i.e. providing that $\dot{\omega}\neq0$). The greater the mass, the greater the inertia of the system and accordingly, the slower is its response and the smaller its maximum whirl amplitude.

It is appreciated that all these deductions are concerned solely with the very simple idealised system considered, yet the solution of acceleration equations is obviously so complicated that it would be virtually impossible to repeat the analysis for more complex systems. Nevertheless, since a real system is composed of an infinite number of these ideal rotors it appears probable that its behaviour will be somewhat similar to that of a single ideal rotor.

Robertson[4] has stated that the unbalanced

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whirl theory of an ideal rotor is applicable to the primary unbalance whirl of a rotor with distributed inertia, except that the mass used in the equations of motion is then not the actual mass of the rotor but an equivalent mass. Thus the behaviour of a uniform slender shaft should be similar to that of the single rotor analysed. A series of tests has therefore been carried out by the writer upon a total of twelve different shafts of varying sizes and materials in order to confirm the effects of acceleration upon the maximum amplitude of whirl. Experimental limitations prevented accurate assessment of the effect of other factors and no record could be found of any similar experiments which could provide additional data. Nevertheless it was possible to confirm that the influence of acceleration was as predicted and none of the results were at variance with the theory.

It is, therefore, tentatively suggested that designers wishing to keep the amplitude of whirl of a rotor passing through a critical speed to a minimum should :

(1) Make the rotor as flexible and heavy as possible, and provide damping ;

(2) Balance the rotor carefully ;

(3) Accelerate the system through its critical speed at the highest possible rate, remembering that at low accelerations the maximum amplitude is approximately proportional to $\frac{1}{\sqrt{\omega}}$

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The Dispersion of Water Globules in Steam : A Preliminary Study

By D. J. RYLEY*

Traditionally, a wet steam mixture has been specified by quoting a temperature (or pressure) and a dryness fraction. It has long been recognised that while this is sufficient for unique thermodynamic description, it gives no information as to the manner of subdivision of the liquid content either with regard to its size or with regard to its spatial association with the vapour. Size dispersion of liquid globules has been extensively studied in connection with spray analysis and much existing knowledge is relevant in this context. The present article is concerned principally to explore the problems which will require solution before space dispersion of globules can be described mathematically.

PART I

THE term " wet steam " is familiar to every steam engineer. It promotes mental pictures of some kind of mixture in which both water and saturated vapour are together associated in a pipe, heat exchanger, l.p. turbine, and so on. The term is vague and usually employed qualitatively except where a " dryness fraction " is specified. It has long been recognised that the term " dryness fraction " conceals a great deal of ignorance, and this is often tacitly admitted by referring to the dryness fractional as " nominal," or " apparent." The significance of these adjectives is that they imply reservations concerning the manner in which the liquid and vapour are physically associated in the common enclosure.

Symbols

d—Diameter of globule.
R—Cumulative volume (or weight) greater than diameter d.
D—Absolute size constant } in Rosin-Rammler Equa-
q—Distribution constant } tion.
a, b—Constants.
d_g—Geometric mean diameter of globule.
σ_g—Geometric standard deviation.
h—Constant.
Sg—Interglobular distance.
x—Dryness fraction.
V_s—Specific volume of saturated vapour.
ρ_w—Saturated water density.
ρ_s—Saturated vapour density.
g—Acceleration due to gravity.
g_c—Newtonian constant.
ω—Angular velocity.
r—Radius of arc.
n—Total number of globules in population.
p—Lattice pitch.
y_1, y_2, &c—y-co-ordinates of impressions.
d_1, d_2, &c—Deviations from ideal space positions.
N—Number of pitches.
σ—Standard deviation.
Δ_x, Δ_y—Interval between adjacent x and y co-ordinates respectively.
μ—Denotes micron; $1\mu = 10^{-3}$mm.

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For flowing steam in continuous motion, the meaning to be attached to the idea of dryness fraction has been explored elsewhere by the writer,[1] but it should be realised that the numerical specification of dryness fraction can at best merely define the respective weight proportions of liquid and of vapour which are associated together within a given space, or, what is not necessarily the same thing, during a given time interval.

To describe more exactly the nature of wet steam in a given context it is necessary to adduce further information under two main headings. Thus reference must be made

(*a*) To the manner in which the entire mass of liquid is subdivided into smaller discrete masses, and

(*b*) To the manner in which these smaller masses are dispersed through the volume jointly occupied by vapour and liquid.

Stated otherwise, the liquid content is dispersed both in size and in space and the present article is concerned to discuss the nature of these dispersions and to suggest methods whereby they may be characterised analytically. Such an attempt encounters a number of problems which will be explored at some length as a necessary preliminary exercise.

The general subject of dispersion in size has already received considerable attention from workers interested in particulate substances and in sprays, and a great deal of knowledge existing in these fields is applicable to the case of water droplets entrained in steam. Size dispersion will, therefore, only be treated superficially in the ensuing paragraphs. This does not mean that it differs in importance from space dispersion, merely that it is better understood. Space dispersion, on the other hand, has received no attention whatsoever so far as the writer knows, and the greater part of the present article will be devoted therefore to this topic.

SIZE DISPERSION

A representative sample of suspended droplets in wet steam, which is large enough to be statistically significant may be expected to show certain characteristics in its size frequency distribution and in the respective magnitudes of the extreme values of size. In any situation, the upper limiting size of a suspended drop depends upon : (1) The rapidity with which it falls out of suspension due to gravity ; (2) Its response to centrifugal forces tending to throw it out of suspension ; (3) Its resistance to fracture caused by aerodynamic or mechanical agencies. Collectively, these agencies will, in normal circumstances, impose a definite upper limit to size by removing the larger drops. The limiting upper size will clearly depend on the context. One may, for example, expect to find much larger droplets temporarily in suspension in the lower part of a condenser where the atmosphere is reasonably quiescent than towards the end of an l.p. turbine where it is in rapid and turbulent motion. Still smaller droplets may be expected towards the exit of an efficient steam separator.

The lower limit of size is less easily appraised. For steam condensing by self-nucleation, the smallest droplets having any permanency of status will be at the critical size corresponding to the prevailing limiting supersaturation ratio and pressure. This size is far too small for detection by any known sampling method, and such droplets are not of practical consequence. If, as is more usual, steam is condensing upon a cool boundary the liquid will become detached and the smallest droplet will depend upon the local influences enumerated in (1)–(3) above. To fix some ideas of probable limiting lower size it may be stated that provided no supersaturation exists, and the population has, therefore, " grown " thermodynamically, all known fracturing agencies will not reduce any significant proportion of the droplet population below about 10μ in diameter.

Between the extreme sizes, the size frequency distribution curve for most cases will be broadly similar to that for artificially produced sprays exhibiting a main modal size together with less pronounced subsidiary modal sizes. An example is shown in Fig. 1. It should be emphasised that there is no reason why the frequency distribution should follow any simple mathematical law as for example, a normal distribution curve. It is customary, when con-

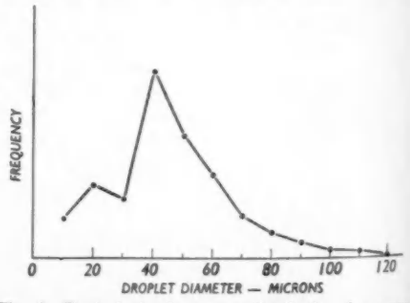


Fig. 1—Typical size-frequency distribution for spray

sidering sprays, to regard the ideal spray as one which is monodisperse in size, and to express numerically the extent of the polydispersion. This outlook has arisen because the ideal practical fuel atomiser, insecticide dispenser, &c., is one which produces the greatest uniformity in size together with the greatest subdivision. It is convenient to retain this outlook in wet steam work.

It is not proposed to examine here the mathematics of size frequency distributions in sprays, but for completeness the most widely-accepted equations are quoted :

(1) The Rosin-Rammler[2] Equation

$$R=exp.\left[-\left(\frac{d}{D}\right)^{q}\right] \quad . \ . \ . \quad (1)$$

where R=cumulative volume (or weight) of droplets of diameter greater than d expressed as a ratio of the total volume (weight) of the sample, D is the absolute size constant and characterises the general magnitude, and q is a distribution constant which increases with the uniformity.

(2) The Roller[3] Equation

$$W=a\sqrt{d}\,.\,exp.\left(-\frac{b}{d}\right) \quad . \ . \ . \ . \quad (2)$$

where W=weight per cent of all droplets having diameters less than d and a and b are constants.

(3) The Hatch-Choate[4] Equations

There are three of these equations having the general form

$$\log d^{h}=\log d_{g}^{h}+a\log^{2}\sigma_{g}$$

where d is one of three statistical diameters, d_g the geometric mean diameter, σ_g the geometric standard deviation, h is an integral exponent of value 1–3 inclusive and a is a constant.

Space Dispersion

In the following paragraphs we shall be concerned solely with the positions in space occupied by the discrete masses of liquid which are collectively associated with the dry saturated vapour. If a given mass of liquid has a continuous interface with the vapour : will normally be in the form of a drop (d>300 microns) or droplet (d<300 microns) and will be in suspension, at least temporarily. A given globule will not generally be stationary with respect to the vapour surrounding it and will therefore be subject to some deflection from the spherical shape. In the great majority of cases, however, the globule considered will be smaller than the equivalent sphere of 1000 microns diameter, and often in the range 10–500 microns, and on account of its high ratio of surface/volume its deflection will be negligible. The space position of the centre may therefore be taken as that of a sphere.

The ideas to be presented are conceived against a background of moderate steam pressures and low values of wetness fraction. Whilst not wishing to put precise limits on these quantities, the writer has in mind pressures up to about 250 lb per square inch absolute, and values of wetness fraction up to about 20 per cent, thus embracing l.p. turbine conditions, and conditions within inertia separating devices and so on. Cases where the wetness fraction is very high, as in boiler tubes and geothermal discharges, are outside the present scope.

It is not widely appreciated what a small aggregate volume is occupied by liquid in a typical application and how great is the mean interglobular distance in relation to the globule diameter. If the globules are assumed to be "packed" in a saturated atmosphere in such a manner that each occupies the lattice point of an imaginary rhombohedral lattice, which is the closest possible regular "packing," it may be shown[5] that the ratio of interglobular distance, Sg, to globule diameter d is closely given by

$$\frac{Sg}{d}=3\cdot58\left[\frac{x\ Vs}{1-x}\right]^{1/3} \quad . \ . \ . \quad (1)$$

where V_s is the specific volume of saturated vapour and x is the dryness fraction. This function has been plotted for a range of low pressures at high dryness fraction and is shown in Fig. 2.

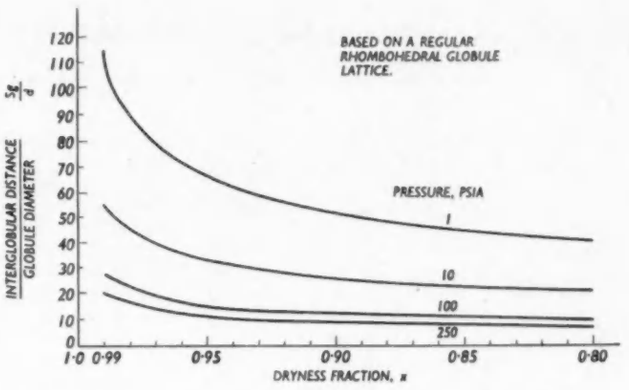


Fig. 2—Variation of ratio of interglobular distance/globule diameter with pressure and dryness fraction

In general, the whole water content will not be concentrated in the aggregate droplet population ; some fraction of it will be lying at the bottom of the available space as a connected or disconnected liquid mass. Again, some may be in contact with the boundary as a film which is in process of draining and which at any time may reach an exposed edge and be re-entrained. When such a mixture is being described, the term " wetness fraction " refers to the entire liquid content, but for the purpose of space dispersion analysis it is necessary to decide whether the entire liquid content should be recognised or only that in suspension at the time of sampling. In many cases, though not all, when the liquid has undergone deposition it has ceased to be a potential influence in so far that it will be led away by a drain or separator or prevented by gravity or surface tension from re-entrainment. In any case it is simpler and more meaningful to attempt to analyse the space dispersion in terms of discrete globules in flight.

The suspended droplets are subject to three main influences :

(*a*) The effect of gravity is always present although it may not be the predominating influence, and it acts on the globule population as a whole tending to cause vertical sedimentation. The gravity force is given by

$$F_g=\frac{\pi d^3}{6}(\rho_w-\rho_s)\frac{g}{g_o} \quad . \ . \ . \quad (2)$$

where $\rho_s=1/V_s$, ρ_w is the saturated water density and g and g_o are respectively the gravitational and Newtonian constants.

(*b*) If the mixture is moving in the arc of a circle, the globule population as a whole is subject to a centrifugal force, which for an individual globule is given by

$$F_c=\frac{\pi d^3\,\rho_w\,\omega^2 r}{6g_o} \quad . \ . \ . \quad (3)$$

where ω is the instantaneous angular velocity in an arc of radius r. If a globule moves towards the outside of a bend it can only do so by displacing vapour inwards. The effective centrifugal field is therefore

$$F_c=\frac{\pi d^3(\rho_w-\rho_s)\omega^2 r}{6g_o} \quad . \ . \ . \quad (4)$$

(*c*) If the flow is turbulent, which will normally be the case, the random motions of local elements of vapour will promote the appropriate random responses by globules in their locality.

At the critical state $\rho_w=\rho_s$ and effects under all the headings (*a*), (*b*) and (*c*) disappear, and the mixture moves as if homogeneous. The present concern is with low pressures for which $(\rho_w-\rho_s)\simeq\rho_w$.

In order to clarify some further ideas it is convenient to consider two specific cases. As a first example consider the case of a droplet population suspended in quiescent saturated steam, i.e. a non-flow process, and undergoing sedimentation. If the total population is regarded as a number of sub-populations of droplets uniform in size and regular in space dispersion then reflection will show that in the absence of coalescence, which could only occur following the comparatively rare event of collision, each population falls independently as a whole with terminal velocity increasing with the size. Each population, in fact, falls through the others whose members are smaller in size, and a space analysis (or indeed a size analysis) would not reveal any variation with time until all the largest droplets had fallen past the sampling station. Thereafter, both size- and space-dispersion will exhibit the continuing pattern of sedimentation. A given actual population will not, of course, be regularly dispersed in space, and the space dispersion at a given station would show a continuously changing pattern without any systematic trend. The existence of active sedimentation, therefore, might be difficult to establish merely from an analysis of space dispersion at given time intervals.

Consider as a second example, the case of wet steam traversing a horizontal bend in a pipe and let Fig. 3 represent the space positions occupied by the globules as they move towards the outside of the bend. A comparison of the space dispersion at, say, sections A and B betrays immediately the effects of centrifugal action, and the variation of size dispersion endorses it. If now, instead of a pipe, an imaginary " stream tube " within a turbine, say, be envisaged, a

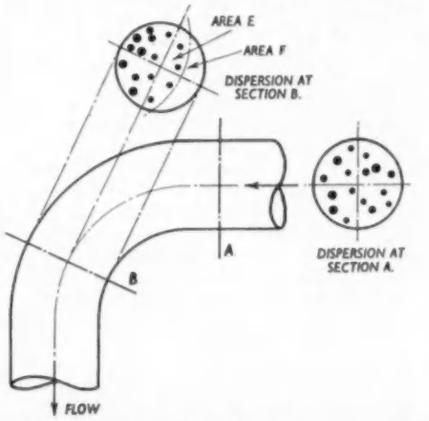


Fig. 3—Variation in space and size dispersions around horizontal bend

Technical Contributors Section (*continued*)

similar space dispersion change obtained experimentally will give a clear indication of curvature in the stream tube.

In the examples just cited it is clear that a space dispersion analysis may yield either no information of the history of globule movement as in the first case, or clear unambiguous information as in the second case. It is not possible to affirm in general whether a space dispersion analysis would or would not yield useful practical information, but there are certainly many cases in which an analysis, if it could be made, would yield results of immediate value. This claim may readily be illustrated by a simple example as follows. Suppose that a wet steam mixture is in transit through an experimental separator of the cyclone type, and the optimum length of the curved path, not readily susceptible to analytical calculation, is in doubt. A dispersion analysis conducted within the stream near the outlet may reveal that a fairly dense population of globules is only marginally separated from the wall, and that by extending somewhat the length of path, precipitation will be accomplished and the separating action improved.

It seemed worth while to the writer to pursue these ideas further as it does not appear to have occurred to any steam engineer that they might be usefully exploited at a later stage in the development of steam machinery. Accordingly an attempt will be made to review and define some of the problems which will require solution before a mathematical approach is possible.

The methods used for describing space dispersion should be those normally employed for describing the characteristics of statistical populations in general and it should be recognised at the outset that no set of parameters can define completely a space dispersion, for complete definition requires co-ordinate reference to every individual globule. One problem, therefore, will be (as in the case of spray size dispersion) to determine how many quantities must be specified to give the desired degree of precision. The decision as to how much information should be embodied in the specification is influenced by pragmatic considerations and will vary from case to case.

The space dispersion will, of course, be three-dimensional, but it is difficult to see how any technique can be devised which will provide information concerning the third dimension from a single sampling. It is difficult, but not wholly impracticable, to obtain accurate information concerning space dispersion in two dimensions. A sedimenting dispersion, for example, can be caused to leave impressions on a prepared horizontal slide. The case of greatest industrial importance is beyond doubt that of the l.p. steam turbine, and here the first successful sampling technique will almost certainly involve the short time exposure of a prepared surface perpendicular to the flow. The failure to do justice to the third dimension may not, in many cases, be as serious as might at first be supposed since the succession of globules along a given stream tube will tend to be less polydisperse than that perpendicular to it, which latter is the consequence of flow stratification caused by upstream obstructions.

The problems associated with the actual sampling will not here be discussed in detail, but it is clear that sampling will have to take place over a small area of flow, and if the entire flow area is to be explored, it will be necessary to repeat the sampling procedure at sufficient stations to give such coverage. It would seem therefore that the analysis of a sample should be made *per se* without reference to the surrounding samples, and that the particulars of the sampling area as regards extent, co-ordinate position, dimensions, total population of impressions, &c., should be given separately. If this is not done, some anomalies occur which are difficult to resolve. Thus reverting to Fig. 3, section B, the question arises as to whether the analysis should be based on the characteristics of the dispersion within the area E of the flow cross section where there are globules, or whether it should take cognisance of the entire flow area, $E+F$. The solution might be thought to consist of the former together with an Occupation Factor, defined as $O=E/(E+F)$, or a Vacancy Factor, $V=F/(E+F)$. That this idea is inadequate may be appreciated if the dispersions (*a*)–(*g*) in Fig. 4 are studied. In each of the

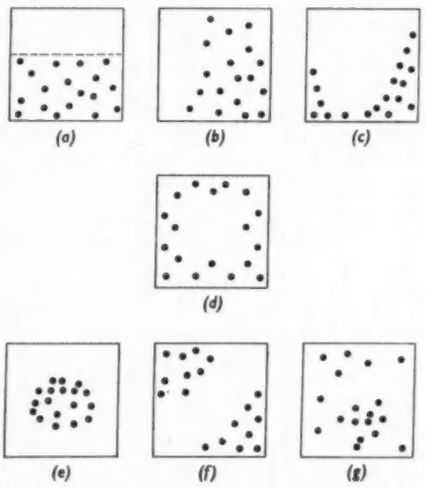


Fig. 4—Imaginary patterns of globule space dispersion

cases (*a*) to (*e*), the value of O might meaningfully be stated because a boundary can readily be envisaged as shown in (*a*). If, however, the same number of globules are redistributed as in (*g*), it is impossible to define convincingly which are areas of occupation and which of vacancy. A statement of the co-ordinates of the centre of gravity of the dispersion may also be ambiguous as a comparison of cases (*d*), (*e*) and (*f*) will show. It would seem, therefore, that the overall analysis should consist of subsidiary analysis within defined adjacent areas. Thus in Fig 5, which depicts a circular flow area, the sampling areas would be, say, 1, 2, 3, 4, &c., and for each it would be necessary to determine as many statistical data as were justified by the problem in hand. Sampling within the unnumbered space near the boundary would present considerable difficulties as globule population concentration might here be high locally, and deposited liquid has been excluded from the analysis.

The choice of the size of the sampling areas 1, 2, 3, 4, &c., will require a considerable circumspection in the light of the following points at issue :

(*a*) If the sampling area is too great it will disturb the flow unduly and may render impossible any corrections.

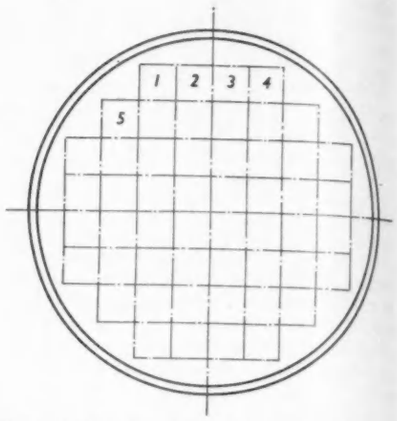


Fig. 5—Distribution of individual sampling areas

(*b*) If the area is too great the resulting analysis will be too coarse.

(*c*) If the area is too small in relation to the globule density the population of impressions will be insufficient for adequate statistical appraisal.

(*d*) The area should preferably be square or rectangular to avoid distortion in the analysis of results if a Poissonian distribution of intervals is under test.

PART II

An attempt in made in this part to explore some of the mathematical difficulties which attend the attempt to describe analytically a space dispersion of globules. Any satisfactory analysis must conform to the following desiderata :

(1) The mathematical procedures, if they are to be suitable for routine work, must not be lengthy, complicated or obscure.

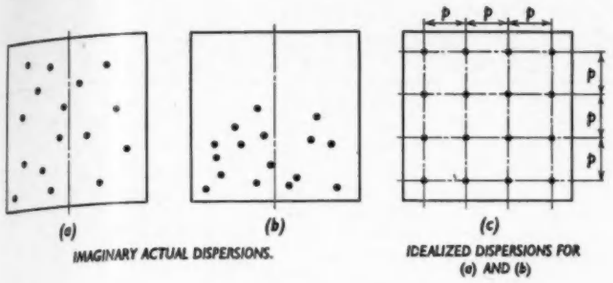
(2) It must be possible to make the necessary practical measurements conveniently and rapidly from the exposed slide or other sampling device.

(3) The descriptive parameters must give values which conform to what is intuitively recognised on inspection as uniformity or heterogeneity, and the same constant (or constants) must not purport to describe dispersions which engineering commonsense and acumen adjudge to be manifestly different.

Analysis can conveniently proceed by measuring the deviation between the space characteristics of an actual dispersion and those of an idealised or reference dispersion. There are two opposite ways in which the reference dispersion may be defined : (*a*) by conformity to an arbitrary pattern ; (*b*) by the total absence of pattern. These are now treated separately and approaches to analysis suggested for each.

Dispersion from a Uniform Pattern

It is assumed that a sampling slide (or other device) is exposed within the steam flow and impressions are obtained thereon which are representative of the two-dimensional space dispersion obtaining within the undisturbed wet steam under test. Figs. 6 (*a*) and 6 (*b*) show samples in which the same aggregate number of impressions ($n=16$ in this case) occur. Whilst neither sample is spatially uniform, the uniformity of (*a*) exceeds that of (*b*). Inspection reveals that sample (*b*) is less uniform than (*a*) only as a consequence of displacements in the



IMAGINARY ACTUAL DISPERSIONS. IDEALIZED DISPERSIONS FOR (a) AND (b)

Fig. 6

y-direction, but about a vertical centre line they are equally symmetrical.

The pattern, or ideal condition, from which Figs. 6 (*a*) and (*b*) are departures may be envisaged as shown in Fig. 6 (*c*) where the total impressions *n* are arranged symmetrically within the sampling area. The impressions have uniform pitching *p* with $\sqrt{n}-1$ complete pitches in each direction. It might appear that a coefficient describing the dispersion might reasonably be based on the aggregate deviations of the several impressions from their "idealised" lattice points. Thus in Fig. 7 one may observe that the

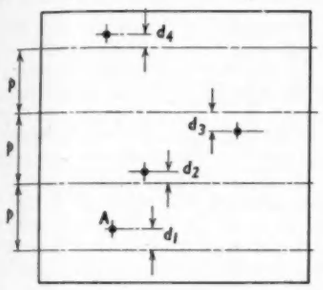


Fig. 7

impression *A* has a *y*-displacement of d_1 from its lattice line, and define an overall *y*-disperson as $\Sigma\ (d_1+d_2+\ldots)$ without regard to the signs of $d_1, d_2 \ldots$. A difficulty is incurred, however, due to the fact that in practice one is proceeding not from a predetermined lattice to a dispersion, but in the reverse direction. It is required, given a dispersed sample, to place the idealised lattice. If, in the ideal case, Fig. 6 (*c*), the entire lattice is displaced, say, in the *y*-direction independently of the impressions, all the latter acquire this deviation, so that while the impressions are, *per se*, fully uniform, a fictitious dispersion coefficient is thus introduced. From a practical standpoint this means that if the lattice is imagined to be symmetrically placed on the sample area in the manner of Fig. 6 (*c*), then if it is subject to any small movement the numerical value of the dispersion will alter whether the actual dispersion is uniform or not. It is clear, therefore, that given the actual disperse sample, the lattice from which deviations are to be measured must be placed so as to avoid ambiguity, and this may be done by placing the lattice so that the sum of the squares of the deviations is a minimum. The procedure is as follows :

Let *OX* (Fig. 8), be the base line for *y*-measurement. Consider a total of *n* impressions *A*, *B*, *C*, &c., having arbitrary dispersions as shown. Let the respective *y* co-ordinates be $y_1, y_2, y_3 \ldots y_n$. Let $d_1, d_2, d_3 \ldots d_n$ be the respective deviations from the appropriate reference line. The lattice lines are at any pitch *p*, and the lowest is at a distance *y* from *OX*. It is assumed that there are $N+1$ lattice lines each having $n/N+1$ deviant impressions. The individual deviations are

$$\begin{aligned} d_1&=y_1-(y+N'p)\\ d_2&=y_2-(y+N'p)\\ &\ldots\ldots\ldots\\ d_n&=y_n-(y+N'p) \end{aligned} \qquad (1)$$

where N' is zero or any integer such that $N' \leqslant N-1$ and has the value appropriate for each lattice line. Let *S* be the sum of the squares of the deviations

$$S=[y_1-(y+N'p)]^2+[y_2-(y+N'p)]^2 + \ldots [y_n-(y+N'p)]^2 \qquad (2)$$

Evaluating dS/dy and equating to zero to give the optimum lattice position yields

$$y=\frac{\Sigma(y_1+y_2+\ldots\ldots y_n)}{n}-\frac{N}{2}p \qquad (3)$$

A similar treatment gives the optimum position for the vertical lattice lines

$$x=\frac{\Sigma(x_1+x_2+\ldots\ldots x_n)}{n}-\frac{N}{2}p \qquad (4)$$

Inspection of Equations (3) and (4) reveals that the lattice must be so placed that one lattice point is at the centre of gravity of the impressions. The number of lattice points will be chosen equal to the number of impressions, so that for a square lattice the number of pitches in each dimension will be $N=\sqrt{n}-1$. The problem then arises as to which impressions should be allocated to a given lattice point, and this can be done in *n!* different ways involving a large range of possible aggregate dispersions. That this allocation is a separate problem from that of placing the lattice can be seen by recognising that for any given set of allocations, equations (3) and (4) define the lattice positions which give the aggregate *x* and *y*-dispersions their minimum respective values, but the numerical value of the minimum will vary according to the allocation.

To illustrate the above method, consider Fig. 9, case (*a*) in which a sample is shown which is not very disperse in either the *x*-direction of the *y*-direction. The lattice position is calculated by the above method, and shown correctly placed in the figure. To allocate an impression to a lattice point, an allocation diagram is drawn as shown below in which the likely claimants for a given point are displayed vertically and horizontally. For this case, the allocation is immediately clear, and if there are, say, conflicting claimants to two points it is easy to decide their relative claims by finding which assessment yields the minimum aggregate dispersion. Case (*b*) (Fig. 9), on the other hand shows a sample in which the *x*-dispersion is small, but the *y*-dispersion is considerable. The allocation diagram is now much more difficult to construct, since it is impossible to assess at sight the correspondence of many impressions with their optimum lattice points, as the reader may verify for himself by attempting to complete and interpret the allocation diagram.

Provided that the sample is not greatly dispersed in either direction, its dispersion can be stated in terms of the standard deviations σ_x and σ_y from the optimum lattice. Since, however, these are only meaningful in relation to the pitch *p*, the "dispersion coefficients" may be defined respectively as

$$D_y=\frac{\sigma_y}{p}\ ,\ D_x=\frac{\sigma_x}{p} \qquad (5)$$

The choice of the number of impressions *n* is arbitrary and is a matter for compromise. Clearly *n* must be sufficiently large for the idea of dispersion to be statistically significant, but sufficiently small to permit the above mode of treatment. It should be borne in mind that both D_x and D_y will show continuous variation with sampling location and to a less extent will vary for a given location with time.

The adoption of a method of measuring space dispersion from a uniform arrangement taken as standard would secure the following advantages :

(1) It would permit the use of Cartesian co-ordinates.

(2) It is simple in concept and would not require difficult experimental measurements or computations.

Conversely, it would be attended by the following disadvantages :

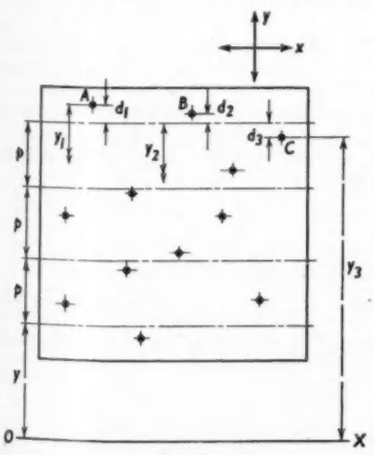


Fig. 8

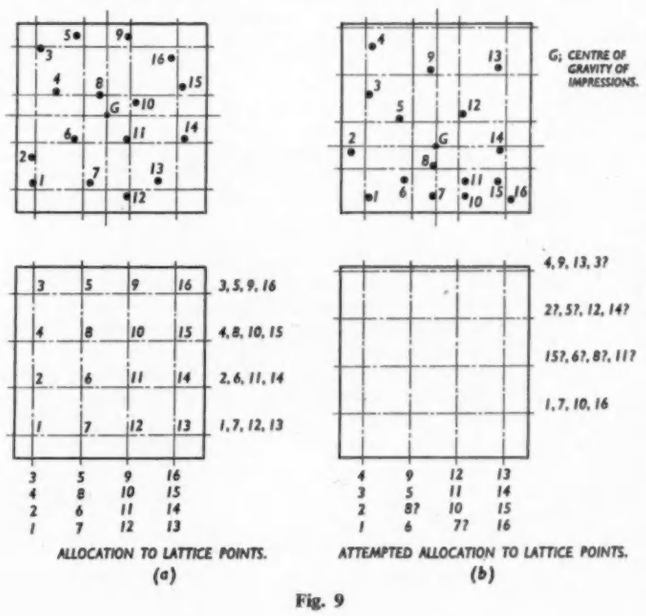


Fig. 9

Technical Contributors Section (*continued*)

(3) It would become difficult to apply for large values of D_x and/or D_y, and for large sample populations.

(4) It is artificial in the sense that a uniform cubic space arrangement of globules could not conceivably occur in practice.

This second disadvantage serves to introduce the discussion of an alternative possibility for defining a standard dispersion.

Dispersion from a Condition of Randomness

Consider that wet steam is flowing up or down a long vertical lagged pipe. The flow is assumed to be fully developed and turbulent and attention is focused upon the centre of the flow remote from the boundary. It will be agreed that whatever patterns or space discrimination may earlier have existed among the globules due to an obstruction, bend, &c., they will have died out after a suitable length of uninterrupted adiabatic flow. It may be argued, therefore, that randomness and not uniformity should be taken to represent the standard condition from which to measure space dispersion. Thus any agency which promotes a pattern in the space distribution, i.e., confers upon it any distinguishing characteristics, such as gravity in the case of horizontal flow, is disturbing the normal state of affairs and its effect should be measured directly by any quantitative index purporting to describe space dispersion. If a sample of impressions is available it is a simple matter to ascertain whether they are randomly dispersed in the two-dimensional field. It is necessary to test if the successive intervals along a given direction from one impression to the next succeeding one conform to a Poissonian distribution, and this may be done by standard statistical procedure, of which one method is to analyse the number of impressions falling within the individual cells of a square mesh. The method here employed is as follows. The successive intervals, say, Δy_1, Δy_2 . . . are measured and ranked in decending order of magnitude R_1, R_2 . . . and Δy is plotted against log R. A straight line results if the dispersion is random for the direction chosen and its slope is a measure of the extreme variation in Δy. Fig. 10 (*a*) shows an imaginary

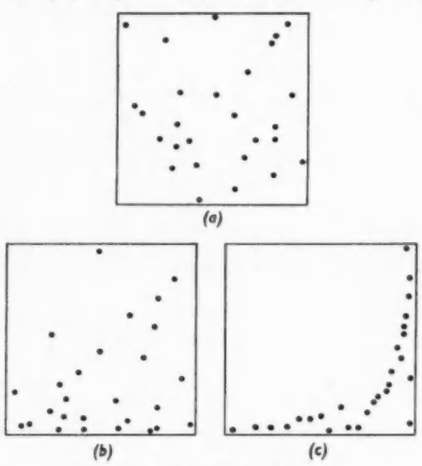


Fig. 10—Random dispersions

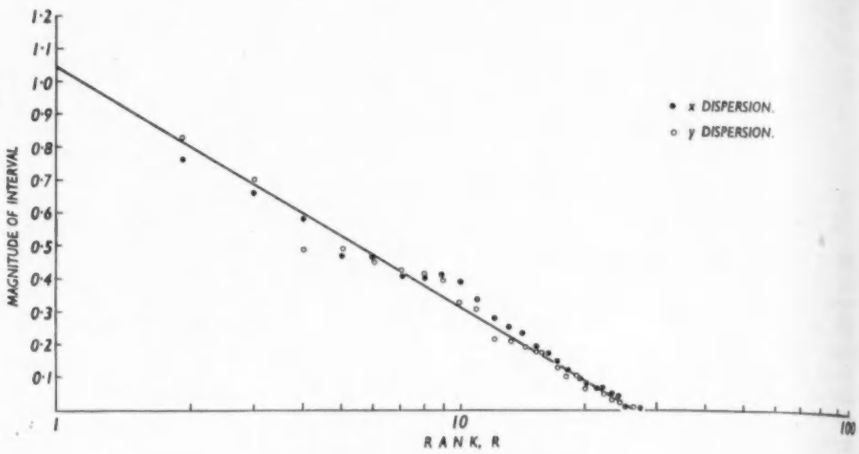


Fig. 11—Test plot for random dispersion

limited population of droplets which has been artificially randomised in both x- and y-directions by dividing the total area into cells and making the presence of an impression dependent upon the toss of a coin. A plot of $\log_{10}R$ against Δy and Δx is shown in Fig. 11 and both relations are seen to be substantially linear. The fact that a dispersion is random in space does not, however, necessarily imply the absence of any distinguishing features. Thus if the dispersion of Fig. 10 (*a*) is considered, which, as drawn, is devoid of pattern, it is apparent that the intervals Δy may be re-arranged without altering the plotted data of Fig. 11. This has been done in Fig. 10 (*b*) in which the intervals have been arranged in ascending order of magnitude in the positive y-direction. The intervals Δx may likewise be rearranged and Fig. 10 (*c*) shows case (*b*) with these intervals arranged in descending order of magnitude in the positive x-direction. The plot given in Fig. 11 is still valid for Fig. 10 (*c*), which dispersion presents a very different appearance from that of Fig. 10 (*a*). The probability of an ordered sequence of intervals arising in experiment is, of course, extremely remote and becomes more so the greater the population, and it may be affirmed that, in general, patterns in the impressions would not be the result of chance dispositions, but an indication of some of the influences described earlier.

It is believed to be unprofitable at the present stage to try to formulate statistical tests for assessing departure from randomness, but this approach would appear to be more profitable than its alternative described in section 2 for the following reasons

(1) It could be employed with a population of any size, and the larger the population the smaller is the probability of fictitious patterns arising by chance.

(2) Experimental measurements could readily be made.

(3) A variety of statistical methods is available for describing patterns.

Conclusions

The above paragraphs have explored, in an elementary way, the two main alternative possibilities for space dispersion analysis. It would seem that the "standard" dispersion is more conveniently conceived as being random in a plane perpendicular to the flow than at the intersection points of a Cartesian lattice. No attempt has been made to formulate a mathematical method for assessing departure from the random condition, the view being taken that it is better to examine this problem in the light of experimental data from known influences than as an abstract exercise in statistics.

It would seem probable that the earliest appraisal of experimentally obtained space dispersions would require methods less refined than those obtained by exploiting either of the above approaches. Indeed, droplet population density n, together with $\partial n/\partial z$ whose z is a defined direction, for a defined sampling area within the flow, would probably suffice for preliminary work.

Underlying all that has been written above is the supposition that it will prove possible to obtain a record, by internal sampling, of the space dispersion of steam-borne droplets within the flow locality which it is desired to analyse, and that this dispersion will not be unrecognisably altered by the errors inevitably imposed on it by the sampling method. The practical problems and errors associated with such sampling, both of which are severe, are currently under study at Liverpool University.

Acknowledgment

The suggestion that random space dispersion might be taken as a standard was made to the writer Mr. M. C. K. Tweedie, of Department of Applied Mathematics, Liverpool University, and his interest in the present problem is gratefully acknowledged.

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Drakelow-"B" Power Station

The 480MW Drakelow-"B" power station, near Burton-on-Trent, was formally opened on October 20, by Colonel Sir Ian Walker-Okeover, Bt., Lord Lieutenant of the County of Derby. The main generating plant consists of four 120MW turbo-generators and four 860,000 lb per hour boilers with steam conditions at the turbine stop valve of 1500 lb per square inch at 1000 deg. Fah., reheated to 1000 deg. Fah. at 360 lb per square inch. Drakelow-"B", completed in December, 1960, is in the East Midlands Division of the Midland Region of the Central Electricity Generating Board.

DRAKELOW-"B" power station is the second stage of electricity power development by the C.E.G.B. on this site, near Burton-on-Trent. The site extends over 746 acres, bounded by the railway (Leicester–Burton) on the north, by the Burton–Tamworth road on the south and east, and by the River Trent on the west. Thus it is well situated for cooling water from the river and for coal supplies which are delivered by rail, with an average haul of about 10 miles, from the South Derbyshire, Leicester and Nottingham coal fields.

As a power generation centre Drakelow is a post-war entity. When the electricity supply industry was nationalised in 1947 plans were well advanced for the building of two stations, each of 240MW capacity. Work on the first stage of this development was started in May, 1950, and completed in November, 1955. It included station "A," consisting of four 60MW turbo-generators, four 515,000 lb per hour boilers and ancillary plant, together with common works and services for the "A" and "B" stations.

In the meantime the plans for the second stage, Drakelow-"B," had been modified to provide twice the output capacity originally envisaged. By exploiting current progress in plant design it was possible to achieve this increase in overall capacity by installing four 120MW generating units and their ancillaries, with very little increase in the physical size of the station. The fourth 120MW unit was commissioned in December, 1960.

A comparison of the capital costs of the first two stations is interesting. Drakelow-"A," with a gross capacity of 240MW (steam conditions : 1550 lb per square inch gauge at 1060 deg. Fah.) cost £15,500,000 to build or £65 per kilowatt. Drakelow-"B," gross capacity 480MW (steam conditions : 1600 lb per square inch gauge at 1050 deg. Fah. with reheat to 1005 deg. Fah.) cost £229,000 or £48 per kilowatt.

Even more striking technical advances are foreshadowed in the third stage of the development : Drakelow-"C" will consist of two 350MW generating units and two 375MW supercritical generating units with steam conditions of 3500 lb per square inch gauge at 1100 deg. Fah. with reheat to 1050 deg. Fah.

When the three stations are completed it is hoped that much of the original character of the estate will be retained : woodlands bordering the stations are being preserved and improved and 217 acres of land will remain under cultivation.

Restoration of the land at Drakelow is typical of the work being done by the C.E.G.B. on constructional sites, having regard to local conditions. Here large quantities of fine and coarse aggregates of good quality overlie the site and they are being excavated for use in the concrete mix for the foundations of station "C." The empty "lagoons" are being used for disposal of the ash from the "A" and "B" stations. Eventually these areas will be soiled over and restored to the original contours for agricultural use. There is also capacity for ash disposal in disused gravel pits at Branston about 1½ miles away.

Drakelow-"B" (Fig. 1) is sited on the same longitudinal axis as the "A" station, the two buildings being separated by the control room, administration block, stores and workshop which provide common services to the two stations. Geologically the site consists of marl at a convenient level for the use of solid foundations for the main buildings. The boiler house is a steel-framed structure and the turbine hall is framed in reinforced concrete, all the main and ancillary buildings being brick clad.

Boilers

Steam is generated in four single-drum reheat radiant boilers each with an evaporative capacity of 860,000 lb per hour. Other details of the boilers and auxiliaries are tabulated below. On No. 5 boiler (International Combustion) the main superheater temperature control is effected by an interstage spray desuperheater ; the reheat temperature is controlled by tilting burners which are connected for automatic control and by hand-operated by-pass dampers for coarse control. For emergency use there are spray desuperheaters fitted in the reheater inlet pipework. Under abnormal conditions the gas temperatures at the superheater and reheater gas inlets can be varied manually by the operation of gas recirculation fans.

On boilers Nos. 6, 7 and 8 the main superheater is condenser-controlled in the heaters between the drum and the main superheater. The steam temperature at the superheater outlets is automatically controlled through by-pass dampers and there is provision for the emergency use of spray desuperheaters in the reheater inlet pipework. Two rotary regenerative heaters are installed for each of the four boilers. Of the five suction-type roller mills on No. 5 boiler four suffice to maintain the boiler at full load. Dust and grit are removed from the flue gases of all the boilers by centrifugal collecters and electrostatic precipitators.

An "Electroflo" automatic boiler-control system provides constant control of steam pressure, combustion rate and combustion pressure. The rate of fuel and air-flow is controlled in a predetermined ratio, with automatic correction for changes in fuel quality, by the continuous comparison of steam evaporation and the amount of combustion-air used.

The installation combines a pneumatic loading-system with hydraulic and pneumatic power cylinders selected to suit individual duties. All measuring regulators are of the force-balance type.

The desired steam-pressure is maintained by means of a master controller, connected to the steam mains. It converts the changes in steam pressure, which occur with variation in load, into an air-loading pressure for transmission to the individual regulators controlling the combustion rate.

Combustion air is controlled by the air-flow regulator. The inlet vanes of the two f.d. fans are operated in parallel by two positioning regulators which are loaded from a sender relay in the air-flow measuring regulator. Air-flow differential is measured in each of the f.d. fan inlet-ducts by venturi contractions and pneumatic transmitters. The output from these transmitters is summated and the result applied to the measuring regulator, balanced against the master loading-pressure. For normal conditions and changes in fuel quality, corrections are made to the air flow by the steam/air flow-regulator which automatically maintains a definite ratio between evaporation and the quantity of combustion-air used.

The furnace pressure is held constant by the i.d. fan regulator. Inlet vanes of the two i.d. fans are operated in parallel by two positioning regulators which are loaded from a sender relay in the measuring regulator. This measuring regulator senses the combustion-chamber pressure and is independent of the master controller. Remote electrical-setting equipment is provided so that the control-setting can be altered at the control panel to suit combustion conditions

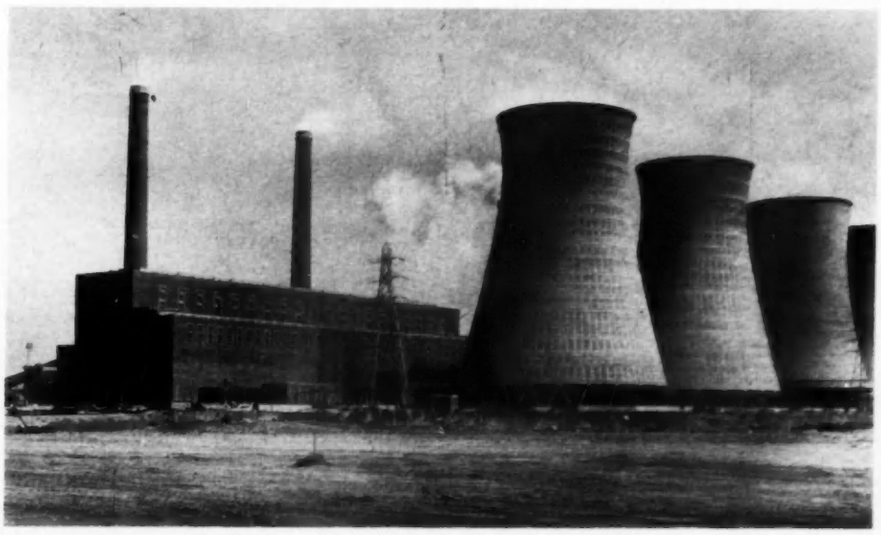


Fig. 1—Drakelow-"B" power station viewed from the site of Drakelow-"C" which is under construction

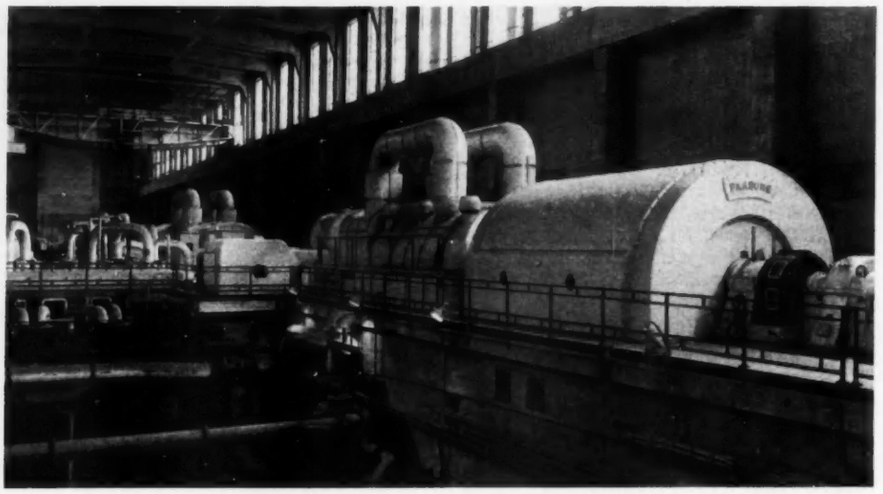


Fig. 2—No. 7 set, one of the four 120MW turbo-generators in Drakelow-" B " power station

(for example during soot-blowing).

Fuel quantity is regulated by controlling the primary air-flow to the mills. The master loading-pressure is balanced against the air-flow differential by the primary air-regulators. The mill output-dampers are controlled by positioning regulators which are loaded from a sender relay in the measuring regulator. Mill suction and tempering air controls are also provided.

Main steam temperature control is effected by characterising the master loading signal in accordance with the expected load/steam temperature relationship, and correcting this signal for any temperature deviations. Diaphragm valves control the quantity of spray-water to the attemperators. Reheat temperature control is effected by regulation of by-pass gas dampers in relation to reheat temperature measurement.

Control of feed-water flow maintains a constant level of water in the steam drum, by regulation of the feed-water control valve. Two valves are provided, each capable of 100 per cent duty by positioning regulators. These regulators are loaded from a sender relay in the measuring regulator, which in turn, receives pneumatic impulses from steam-flow, feed-flow and drum-level transmitters. Comparison of these impulses is so arranged that feed-flow requirements are anticipated by changes in steam-flow, to maintain constant drum level.

The auto/manual sub-panels, provided on the unit control desks, permit the operator to switch the boiler from automatic steam-pressure control to unified manual control, or to individual operation of all regulators.

The main and hot re-heat steam pipework is of 2¼ per cent chromium 1 per cent molybdenum steel. The left- and right-hand main steam pipes are cross-connected, and similarly the re-heat return pipes to the turbines, in order to permit on-load test tripping of either of the turbine stop valves or either of the intercepting valves of the re-heat lines.

Turbo-Generators

The four Parsons 120MW sets (Fig. 2) arranged longitudinally in the turbine room are three-cylinder impulse-reaction machines with a triple-flow low-pressure cylinder. The turbine stop valve steam conditions are 1500 lb per square inch at 1000 deg. Fah. with steam reheated to 1000 deg. Fah. at 360 lb per square inch at the intermediate pressure cylinder inlets. The main speed governor controls the high-pressure steam-admission valves, and an independent auxiliary governor is fitted to regulate the intercepting and unloading valves, an arrangement which allows the auxiliary governors to be set independently of the main governor.

Steam is bled from the turbine at six points to three low-pressure feed heaters including a high-level de-aerator, three high-pressure bled-steam heaters and an evaporator vapour condenser.

The two-shell three-flow surface condenser is designed to give a vacuum of 28·9in of mercury when supplied with 58,000 g.p.m. of cooling water at 58 deg. Fah., air being extracted from the condensers by three 50 per cent duty pumps.

Each turbine is associated with a twin double-effect bled-steam evaporating plant producing a net gained output of 40,000 lb per hour. The hydrogen-cooled alternators, generating at 13·8kV, are rated for continuous operation at 120MW at 0·9 power factor with a hydrogen pressure of 15 lb per square inch, distillate being used in four heat exchangers for hydrogen cooling.

The totally-enclosed air-cooled main and pilot exciters are gear driven at 750 r.p.m. from the main alternator shaft.

Automatic voltage regulation is by a quick-response static equipment incorporating a magnetic amplifier and a twin amplidyne set. The equipment includes a follow-up mechanism which permits a smooth change-over from automatic to manual control.

Each turbo-generator is fitted with supervisory instruments to indicate and record the speed, output, eccentricity and differential expansion.

Two generating units are controlled from each of the two control rooms (Fig. 3) which house the operational control desks,

Main Particulars of Drakelow-" B" Power Station

Boiler Plant :		
Superheater outlet pressure	1600 lb per square inch gauge	
Superheater outlet temperature	1050 deg. Fah.	
Reheater pressure, inlet	425 lb per square inch gauge	
Reheater temperature	1005 deg. Fah.	
Feedwater temperature	435 deg. Fah.	
Steam flow from superheater (C.M.R.)	805,444 lb per hour	
Steam flow from reheater (C.M.R.)	743,647 lb per hour	
Number of boiler unit	5	6, 7 8
Manufacturer	International Combustion	Foster Wheeler
Volume of combustion chambers	82,100 cubic feet	82,000 cubic feet
Type of primary superheater	Two-stage self-draining convection	Radiant and self-draining convection
Type of secondary superheater	Two-stage pendant	Self-draining convection
Material of secondary superheater tubes	1¼% Cr., ½% Mo. 2¼% Cr. 1% Mo.	18% Cr. 8% Ni.
Type of reheater	Two-stage self-draining convection	Two-stage self-draining convection
Material of reheater final stage :		
First stage	1% Cr. ½% Mo.	18% Cr. 8% Ni.
Second stage	2¼% Cr. 1% Mo.	
Economiser heating surface	126,298 square feet	95,040 square feet
Number and type of primary air preheaters	Two rotary regenerative	
Number and type of mill air heaters	Two platen type	Two tubular type
Total heating surface of primary air preheaters	126,000 square feet	115,400 square feet
Total heating surface of mill air heaters	19,440 square feet	6,540 square feet
Combustion Equipment		
Number of mills/unit	Five	Three
Type of mill	Lopulco roll	Double-ended ball
Capacity per mill	31,100 lb per hour	58,900 lb per hour
Mill motors	220 b.h.p., 1485 r.p.m., 3·3kV	600 b.h.p., 369 r.p.m., 3·3kV
Exhausters, number per mill and type	One paddle wheel	Two paddle wheel
Capacity of one exhauster	76,500 lb per hour	29,450 lb per hour
Exhauster motors	240/70 h.p., 1470/960 3·3kV (variable speed)	120 h.p., 1475 r.p.m., 3·kV
Number and type pulverised fuel burners	Twenty tilting type	Eighteen intervane type
Location	Corners	Front wall
Capacity per burner	7800 lb per hour	9820 lb per hour
Number and type of oil burners	Twelve retractable	Eighteen retractable
Locations	Three at each corner	One at centre of each intervane burner
Maximum steam flow on oil fuel	80,000 lb per hour	30,000 lb per hour
Oil-storage capacity	140 tons	

Draught Fans		
F.D. fans per unit	Two, single side inlet, constant speed	
F.D. fan rating	145,000 c.f.m. 10·05in w.g., 90 deg. Fah.	129,000 c.f.m. 8·06in w.g., 100 deg. Fah.
.D. fan motors	496 h.p., 740 r.p.m. 3·3kV	408 h.p., 742 r.p.m., 3·3kV
I.D. fans per unit	Two double side inlet ducts, two-speed	
I.D. fan rating	228,000 c.f.m., 14·65 w.g., 257 deg. Fah.	197,500 c.f.m., 10·73in. w.g., 223 deg. Fah.
I.D. fan motors	1265/720 h.p., 985/740 r.p.m., 3·3kV, two speed	762/477 h.p., 740/590 r.p.m., 3·3kV
Booster and Boiler Feed Pumps		
Number of boiler feed pumps for each boiler/turbine unit	Two, 100 per cent duty	
Type	No. 5 unit Seven-stage centrifugal	Nos. 6, 7 and 8 units Eight-stage centrifugal
Pump rating	965,000 lb per hour	
Pump head	1950 lb per square inch gauge	1970 lb per square inch gauge
Temperature	435 deg. Fah.	
Motors	Squirrel-cage induction, 3·3kV, 2700 h.p. 2980 r.p.m.	
Number of booster feed pumps for each boiler/turbine unit	Two, 100 per cent duty	
Type of pump	Seven-stage centrifugal	
Pump rating	965,000 lb per hour	
Pump head	550 lb per square inch gauge	
Temperature	260 deg. Fah.	
Motors	Squirrel-cage induction 3·3kV, 900 h.p., 1480 r.p.m.	
Turbo-Alternators		
Continuous maximum and economic rating	120MW	
Steam pressure at turbine stop valve	1500 lb per square inch gauge	
Steam temperature at turbine stop valve	1000 deg. Fah.	
Final feed temperature at C.M.R.	435 deg. Fah.	
Vacuum at C.M.R.	1·1in Hg. absolute	
Inlet circulating water temperature	58 deg. Fah.	
Turbines	Three-cylinder impulse reaction with triple flow l.p. cylinder	
Number of h.p. stages	Thirteen	
Number of l.p. stages	Nineteen	
Number of l.p. stages	3×8	
Point of entry of reheat steam	l.p. cylinder inlet	
Reheat steam pressure	360 lb per square inch gauge	
Reheat steam temperature	1000 deg. Fah.	
Exciters. Main/pilot	460V/220V, 1250A/100A	

Fig. 3—Plant control room for generator units Nos. 5 and 6. A similar control room serves Nos. 7 and 8

panels of indicating and recording instruments, alarms and auxiliary plant controls. Telemetering, both electrical and pneumatic, has been used extensively so that live steam and high-pressure water can be kept away from the control rooms.

Local panels, situated near the associated plant, contain indicating instruments and telemetering transmission equipment.

River water for boiler feed make-up is softened before evaporation, and ammonia is removed in a plant comprising a precipitation unit with chemical proportioning gear, stabilising units and base exchange ammonia removal units. This plant has a capacity of 20,000 g.p.h., and two 1,500,000 gallon capacity reservoirs for softened water supply both the " A " and " B " stations.

Two 100 per cent duty booster pumps discharge through the high-pressure heaters to the inlet of two feed pumps, which are each 100 per cent duty and discharge through feed-regulating valves to the boiler. Each booster pump is paired with a boiler feed pump, the standby pair starting up on failure of the running pumps. The feed pump discharge pressure on No. 5 unit is 1950 lb per square inch and 1970 lb per square inch on Nos. 6, 7 and 8 units. The booster and feed pumps are centrifugal, constant-speed machines.

Coal Supplies

Fuel supplies consist of slack, with a small percentage of slurry, of a calorific value within the limits of 7500 to 11,000 B.Th.U. per lb, the ash content being about 19 per cent. Deliveries to the station, averaging 5600 tons per day for the four boilers, are by rail and are handled by three-side discharge wagon tippler weighers. From the tipplers coal can be taken direct by belt conveyor at a rate of 1000 tons per hour to the four 1300 tons capacity boiler bunkers where it is discharged by travelling trippers, or to store where a travelling wing tripper operates on a conveyor running the full length of the coal storage area. Coal is spread over the store by mobile coal-moving equipment, which includes two tractor shovels and a bulldozer.

Coal is reclaimed from store through three ground hoppers, each of 500 tons per hour capacity, with provision for a fourth if required later. Thence the coal is taken by conveyors direct to the station bunkers. Road-borne coal is discharged either direct to a ground hopper or to store. Each tippler is provided with dust-extraction plant.

There are two marshalling yards to handle full and empty wagons for both the " A " and " B " stations, shunting being carried out by diesel locomotives. Magnetic separators are installed on the conveyor belts feeding No. 5 boiler bunker to prevent damage to the mills associated with that boiler. On the other boilers, which are fitted with ball mills, this precaution is unnecessary.

Ash and clinker, collected in dry ash hoppers beneath each boiler, are crushed and ejected by water jet nozzles and conveyed to the ash sump by further jets in the removable nickel-cast-iron lined sluiceways. Three 50 per cent duty sluicing pumps with a capacity of 1900 g.p.m. are installed.

The fines, which are removed from the flue by centrifugal collectors and electrostatic precipitators, drop into storage hoppers. They are then removed by vacuum induced by hydraulic ejectors, and the airborne solids mix with the ejector water to form a slurry, which is sluiced by gravity to the dust sump. Dust and ash slurries are removed from the sumps by three 100 per cent duty ash pumps and two 100 per cent duty dust pumps and transferred to the exhausted gravel pits at Drakelow and Branston. Two 100 per cent duty grinders are installed. Excess slurry from the ash and dust sumps is taken to an overflow sump from which it is pumped to the ash launder of the " A " station.

Cooling Water

Condenser cooling water is drawn from the tower ponds by four condenser pumps which discharge into a common 54in diameter pipe, any pump being able to supply any condenser. From the condensers the water is taken through similar pipes to a discharge culvert and thence to the river. A sill maintains the level in this river culvert, from which three tower pumps deliver water to the towers. Each of the three towers is designed to enable one unit to operate at continuous maximum rating. The two cooling towers associated with " B " station are of ferro-concrete construction and are 307ft high, the capacity being 3·82 million gallons of water per hour.

The mixed flow system, which is interconnected with that of the " A " station, is designed to utilise, as far as possible, the available cooling capacity of the River Trent. All pumps are rated at 62,500 g.p.m., the condenser pumps at 43½ft head and the tower pumps at 57ft head.

River water for direct cooling and make-up is obtained from a riverside pumphouse constructed with the " A " station. There are four vertical-spindle centrifugal pumps, each of 2,000,000 g.p.h. rating, with four cup-type screens installed at the intakes. The water is fed to the " A " and " B " stations through twin concrete culverts which discharge to the cooling tower pond and conduit systems.

Chlorinators

Master vacuum solution feed chlorinators installed with the " A " station are used in the " B " station, each chlorinator being

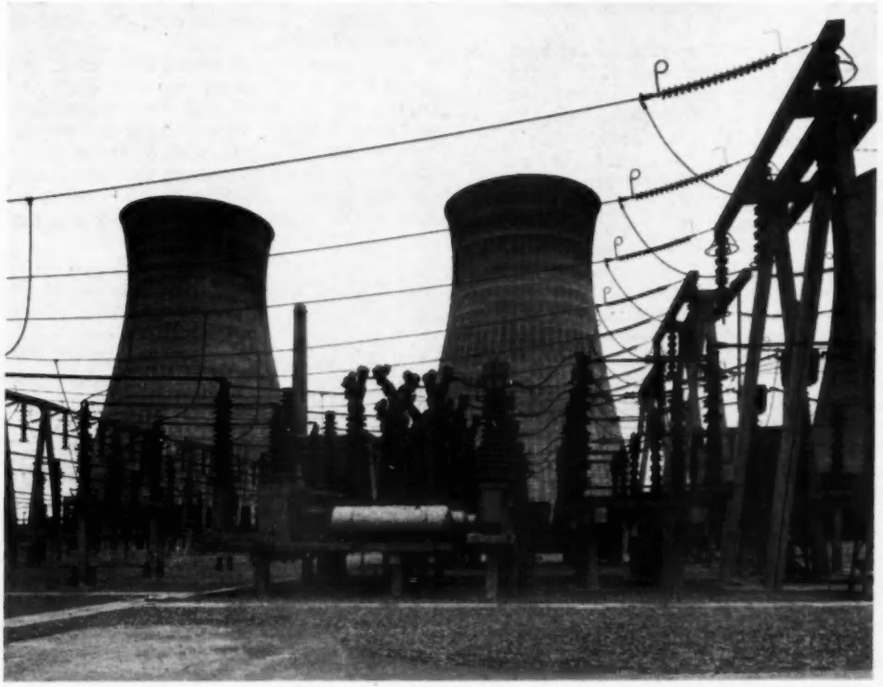


Fig. 4—275kV air-blast circuit breakers, 7500MVA, in outdoor substation at Drakelow-" B "

designed for a maximum capacity of 250 lb of chlorine per hour, with automatic intermittent operation controlled from an electric programme clock.

Station Control Room and Electrical Auxiliaries

The main electrical control room for the 275kV, 132kV and 3·3kV systems of both the "A" and "B" stations is in the administration block, and houses a generator load desk for the "A" station, 275kV, 132kV and 3·3kV controls, the "A" station river water and "B" station circulating water pump motor control desks, the 275kV, 132kV and 3·3kV systems alarm relay equipment panels, the automatic voltage regulators for the "A" station and the generator relay panels and chlorinating programme clock for both stations.

Each alternator is solidly connected by double angle section copper busbars on porcelain insulators in a reinforced concrete flume to a 13·8kV/295kV 125MVA forced oil circulation water-cooled generator transformer, the machines being switched and synchronised at 275kV.

A 10MVA unit transformer is solidly connected to the 13·8kV terminals of the alternator, to supply the 3·3kV auxiliaries. Two 20MVA 132kV/3·45kV station transformers, each comprising two 10MVA banked units, are provided for general station services and standby and starting supplies to the 10MVA unit transformers. Eleven 1MVA, 3300V/435V transformers provide medium voltage supplies for the smaller auxiliaries, lighting and other services. All transformers are oil-filled outdoor equipments.

All motors above 120 h.p. are direct-switched at 3·3kV; motors between 100 and 120 h.p. are 415V machines, controlled by airbreak circuit breakers; the rest of the 415V auxiliaries are controlled by air-insulated contactor gear. Essential standby motor for the turbine oil and hydrogen (cooling) systems are fed from the main station batteries. Most of the motors are squirrel-cage machines, started direct-on-line, but the exhauster, feeder and separator on No. 5 unit are driven by variable speed a.c. commutator motors. The total installed capacity of all the motors is about 60,000 h.p.

The supplies for these auxiliaries are controlled by 3·3kV and 415V switchgear which is single busbar, airbreak, solenoid operated, the ratings being 150MVA at 3·3kV and 25MVA at 415V. The 3·3kV system is earthed through liquid neutral-earthing resistors but the 415V system is solidly earthed.

Outdoor Substation

The main outdoor substation (Fig. 4) is equipped with eighteen 275kV air-blast circuit breakers to control four generators, eight feeders, two bus-couplers, two bus section switches and two 275kV/132kV, 120MVA auto-transformers. Each circuit breaker has a rupturing capacity of 7500MVA with six interrupters in series per phase. The 275kV isolators are electrically operated and are remotely controlled from the main control room.

Single-core oil-filled cables, each of 0·4 square inch cross section, connect the four generator transformers to the substation. They are among the first 275kV cable installations to come into service in this country.

Main Contractors and Sub-Contractors

Mechanical Plant.—Boiler Plant, No. 5.—Main contractors: International Combustion Ltd. Sub-contractors: drums, English Steel Corporation Ltd.; superheaters and desuperheaters, The Superheater Company Ltd.; economisers, Senior Economisers Ltd.; air heaters, James Howden and Co. Ltd.; valves and fittings, Dewrance and Co. Ltd.; sootblowers and control equipment, Hopkinson Ltd.; i.d. and f.d. fans, Davidson and Co. Ltd.; exhausters, Keith Blackman and Co. Ltd.; oil fuel equipment, Wallsend Slipway and Engineering Company Ltd.; mechanical dust collectors, Davidson and Co. Ltd.; precipitators, Sturtevant Engineering Company Ltd.; steam temperature control, George Kent Ltd.; motors, Laurence Scott and Electromotors Ltd.; television equipment—drum level, Hopkinson Ltd.; combustion chambers, Pye Ltd.; remote instrumentation—automatic control, panels and desks, Electroflo Meters Company Ltd., alarm equipment, Standard Telephones and Cables Ltd.

Boiler Plant, Nos. 6, 7 and 8.—Main contractor: Foster Wheeler Ltd. Sub-contractors: drums, Firth Brown Ltd.; economisers, E. Green and Son Ltd.; air heaters, James Howden and Co. Ltd.; valves and fittings, Hopkinson Ltd.; sootblowers and control equipment, Hopkinson Ltd.; i.d. and f.d. fans and mechanical dust collectors, Davidson and Co. Ltd.; oil fuel equipment, Associated Combustion Control Ltd.; precipitators, Simon-Carves Ltd.; steam temperature control, Electroflo Meters Company Ltd.; motors, Laurence Scott and Electromotors Ltd., and Lancashire Dynamo and Crypto Ltd.; television equipment—drum level, Hopkinson Ltd.; combustion chamber, Rank Cintel Ltd.; remote instrumentation—automatic control, panels and desks, Electroflo Meters Company Ltd., alarm equipment, Standard Telephones and Cables Ltd.

Turbo-Alternators and Condensing Plant.—C. A. Parsons and Co. Ltd. Sub-contractors: rotary air pumps, Mirrlees Watson and Co. Ltd.; quick-start air pumps, Hick Hargreaves and Co. Ltd.; evaporators, Aiton and Co. Ltd.; de-aerators, Wm. Boby and Co. Ltd.; motors, Lancashire Dynamo and Crypto Ltd.

Circulating Water Pumps—Drysdale and Co. Ltd.; motors, English Electric Company Ltd. Feed pumps, booster pumps and motors, Harland Engineering Company Ltd.

Coal Handling Plant—International Combustion Products Ltd. Sub-contractors: wagon tipplers and wagon handling plant, Mitchell Engineering Company Ltd.; conveyor belts, British Tyre and Rubber Company; belt weighers, S. Dennison and Co.; tippler weighbridges, W. and T. Avery Ltd.; magnetic separators, H. G. Richardson and Co.; gearboxes, The David Brown Industries Ltd.; fluid couplings, Fluidrive Engineering Ltd.; friction couplings, Twiflex Ltd.; motors (conveyor) Lancashire Dynamo and Crypto Ltd.; motors (tipplers and wagon handling plant), Laurence Scott and Electromotors Ltd.; tippler, control gear, Allen West and Co. Ltd.

Mobile Coal Moving Equipment.—Bowmaker (Plant) Ltd. and Michigan (Gt. Britain) Ltd.

H.P. Steam and Feed Pipework and Valves Nos. 5 and 6.—Stewarts and Lloyds Ltd. Sub-contractors: valves, Hopkinson Ltd., and Dewrance and Co. Ltd.

H.P. Steam and Feed Pipework and Valves Nos. 7 and 8.—John Thompson (Pipework) Ltd. Sub-contractors: valves, Hopkinson Ltd., and Dewrance and Co. Ltd.

Ash Handling Plant.—John Thompson Industrial Constructions Ltd. Sub-contractors: pumps, Gwynnes Pumps Ltd.; motors, Lancashire Dynamo and Crypto Ltd.

Chlorination Plant.—Wallace and Tiernan Ltd.

C.W. Pipework.—Aiton and Co. Ltd.

C.W. Valves.—Blakeborough and Co. Ltd.

Water Treatment Plant.—John Thompson-Kennicott Ltd.

Electrical Plant.—Generator transformers, A.E.I. (Rugby) Ltd. Station transformers, A.E.I. (Rugby) Ltd., and Yorkshire Electric Transformer Company Ltd. Unit Transformers, Crompton Parkinson and Co. Ltd., and Bonar Long and Co. Ltd. 275kV, 3·3kV and 415V switchgear, A. Reyrolle and Co. Ltd. 415V contactor gear, A.E.I. (Manchester) Ltd. Cables, Aberdare Cables Ltd., and B.I.C.C. Ltd.

Civil Engineering Works.—Site clearance, foundations for buildings and plant, roads, dust pipeline and coal store, M. J. Gleeson (Contractors) Ltd.; structural steelwork, South Durham Steel and Iron Company, and Briathwaite and Co. (Structural) Ltd.; conveyor bridges, pipe and footbridge, West Midlands Construction and Erection Company Ltd.; building as per structure, J. Gerrard and Sons Ltd.; ground hoppers and foundations for coal handling plant, Turriff Construction Corporation Ltd.; cooling tower foundations and culverts, Bierrum and Partners Ltd.; cooling towers, Davenport Engineering Company Ltd.; chimneys, D. Theaker and Co. Ltd.

Type 2 Diesel Electric Locomotives for British Railways

The latest series of Type 2 diesel-electric locomotives built for British Railways by the Birmingham Railway Carriage and Wagon Company Ltd., resembles the earlier 1160 h.p. design externally, but the intercooled Sulzer engine is rated at 1250 h.p., and the electrical equipment has been supplied by The General Electric Company Ltd.

IN 1958 the first deliveries began to British Railways of a series of 1160 h.p. B_0-B_0 diesel-electric locomotives having Sulzer engines and Crompton Parkinson electrical equipment (THE ENGINEER, December 5, 1958, page 895). Forty-seven of these locomotives were supplied, all of which are now working in the Scottish Region, and later a further sixty-nine were ordered from the same builder, but with an intercooled version of the original engine, giving 1250 h.p., and electrical equipment by The General Electric Company Ltd. The first of this higher-powered series are now entering traffic. They are to be divided between the Scottish, North Eastern and London Midland Regions.

The locomotives are geared for a maximum speed of 90 m.p.h. (compared with 75 m.p.h. in the earlier series) and the transmission has been designed to absorb the full engine power up to 80 m.p.h., with an insignificant degree of unloading between that speed and the maximum. Starting tractive effort is now 40,000 lb, as against 42,000 lb, and the continuous rating of 25,000 lb at 14 m.p.h. compares with 30,000 lb at 11 m.p.h. in the previous version. The weight with two-thirds fuel supplies is 73·5 tons.

Although generally similar to their predecessors in construction and arrangement, the locomotives incorporate certain improvements based on service experience. Cabs are now fully finished with plastics materials to provide easy-clean surfaces throughout. The driver's and engineer's desks have been equipped with glass fibre panels and access doors, which provide an attractive finish, and allow easy access to the master controller mechanism and to control buttons which do not have to be operated frequently, such as reset buttons fitted beneath the desk tops. The cab floors are now entirely removable by means of lift catches and are covered with an oil-resisting linoleum. The engine room has been provided with a translucent roof trap, moulded in glass fibre reinforced polyester resin, and fitted with quick-release fasteners. Brake equipment, supplied by the Westing-

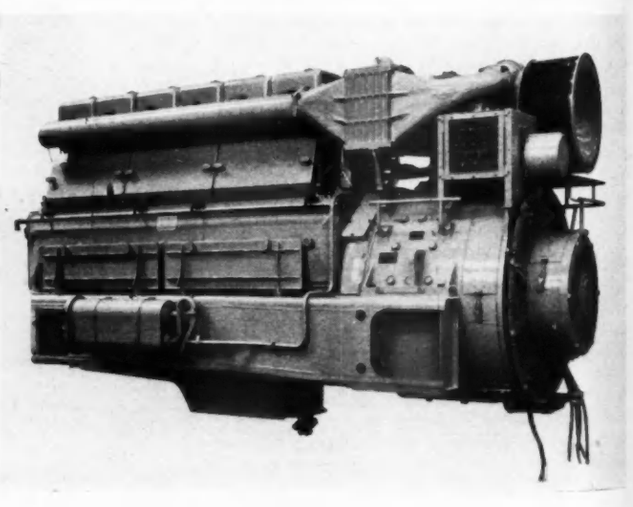


Fig. 1—Locomotive power unit with intercooler. The electrical load regulator and associated resistances are mounted on the generator

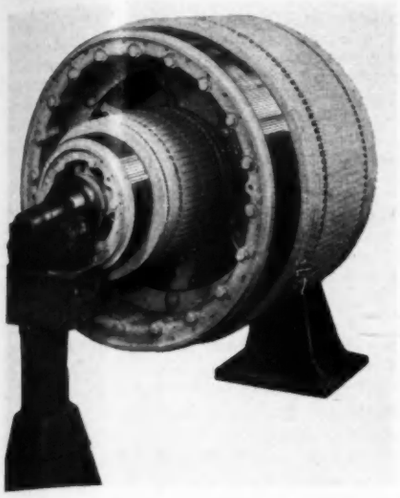


Fig. 2—"Telescoped" construction of main and auxiliary generator armatures

house Brake and Signal Company Ltd., is of the company's standard lightweight design, with four 8in cylinders per bogie.

The power unit (Fig. 1) is the Sulzer 6LDA28-B, the intercooled version of the pressure-charged, six-cylinder diesel engine with 280mm bore and 360mm stroke, and develops 1250 h.p. continuous at 750 r.p.m. Both engine versions are almost identical, the increase in output being achieved by a simple form of charge air cooling, having the intercooler incorporated in the cooling water circuit so that separate radiator elements and an extra pump are avoided. The single intercooler for the "B" version engine is an air-to-water three-flow cooler. The tube stack is fitted directly into a wide portion of the induction manifold between the pressure-charger and the engine. The fuel pump plungers are of larger diameter than in the "A" version to deliver the extra fuel for the increased output. Engine speed is controlled pneumatically by a self-lapping air valve incorporated in the driver's master controller, acting on the engine governor. Automatic adjustment of the electrical output is provided by a G.E.C. regulator mechanically driven from the governor.

The main generator, rated at 805kW, 1940A at 750 r.p.m., is a ten-pole single bearing machine with four field windings—separately-excited, self-excited, reverse series, and starting. Main and auxiliary generator armatures are mounted on a common cast steel hub, which is bolted solidly to the engine crankshaft flange and is carried in a single roller bearing at the outer end. Advantage has been taken of the necessarily large diameter of the medium-speed main generator to recess the auxiliary generator partly into it (Fig. 2), so keeping the overall length of the set the same as with the previous main generator, despite the increase in output. The brush holders are mounted on a rocker which can be rotated by a gear drive to bring them into a convenient position for maintenance. Both machines are self-ventilated by one fan on the main armature which discharges the cooling air downwards to atmosphere through trunking in the underframe. Provision is made on the fan disc for barring the engine by hand. The 57kW auxiliary generator is a six-pole machine with an output maintained substantially constant at 110V by an automatic voltage regulator.

Four axle-hung four-pole traction motors, connected in parallel across the output of the main generator, drive through Wiseman resilient gears. Resilient nose-suspension is provided by "Metalastik" units. As in the generators, the brushgear is rotatable. Continuous rating of the motors is 236 h.p., 485A, 415V, and the gear ratio is 17/60.

The radiator fan is driven by a 16 h.p. motor having two speeds—840 and 1500 r.p.m.—under thermostatic control, the higher speed being obtained by field tapping. Twin Aerex "Hyperform" radial blowers, each supplying cooling air to two traction motors, are driven by a single two-speed machine running as a compound motor at slow speed and a series machine at high speed. Both for this machine and the radiator fan motor, high-speed running is obtainable only after a certain controller position has been reached, thus reducing the loading on the auxiliary generator at low engine speeds.

Two Northey exhausters are driven by integrally-mounted two-speed motors, normally running at the lower speed to maintain vacuum, but being speeded up for brake release under the control of the brake valve contacts. Air for the locomotive brakes and control is provided by a Westinghouse compressor. The combined engine water, oil and fuel supply pump set is driven by a single motor which operates from the battery before the engine is started, and can maintain circulation after the engine has stopped. The combination of oil and coolant pumps in one set ensures that coolant is circulated before the engine will start.

Generator excitation is obtained from the separately-excited and self-excited fields in combination. The output is controlled solely by the automatically-adjusted regulating resistance in the separately-excited field circuit, there being no initial fixed-resistance steps of field control as in previous G.E.C. schemes for Type 2 locomotives, where individual control steps were provided instead of continuous variation of engine speed. The self-excited field is so proportioned as to follow the separately-excited field and provide a reflected form of field variation which, while giving effective control, reduces the size of the load regulator. A reverse series field gives a slight decompounding effect and is also used in conjunction with the short-rated starting field when motoring the engine from the battery.

Each traction motor is protected by an overload relay and a contactor, and in the event of an overload trip the main generator separate field excitation is also removed, thus considerably easing the load on the contactors. Provision is made for cutting out any motor in the event of trouble, permitting the operation of the locomotive on the remaining three motors.

Motor field weakening, in three stages, is introduced automatically by a relay in the main generator separate field circuit, operating in conjunction with the load regulator so as to ensure that the field divert contactors do not close until the generator voltage has been reduced to a suitable value. This limits the current in the traction motors and avoids overload on the engine. Backwards transition is also automatic on rising current demand. The field divert resistors, together with pre-set trimming resistors for the self-excited field, are mounted in the train-heating boiler compartment, while the regulating resistance is combined with the servo regulator in a single unit mounted on the main generator as seen in Fig. 1.

One of the design requirements for the electrical equipment was that the control gear should be accommodated in a cubicle no larger than that in the 1160 h.p. locomotives. It was therefore necessary to design a four-motor reverser in place of the two-motor design used in pairs in previous G.E.C. Type 2 equipments. In order to reduce contact size, silver inserts are used, mounted on silver-plated contact bases, and a modified mechanical changeover arrangement allows a smaller operating cylinder to be used than in the two-motor reversers. Fig. 3 shows the cubicle housing the bulk of the control equipment, with the reverser in the lower right-hand compartment. Auxiliary gear is housed in the left-hand compartment. As seen in this illustration, indication lights identifying faults shown by the general fault indicator light in the cab and certain switches are mounted on one end of the cubicle. In the battery charge circuit the conventional contactor and reverse current relay are replaced by a silicon diode which blocks reverse current.

Fig. 3—Main control cubicle with auxiliary equipment on left and power equipment on right. The four-motor reverser is in the lower right-hand compartment

Letters to the Editor

VARIETY OF PAPER SIZES IN THE U.K.

SIR,—I read with great interest the article on "Variety of Paper Sizes in the U.K. (THE ENGINEER, September 29, 1961, page 537). Whilst facts are stated and interest is created by the article, the authors have not given consumers any indication of how they can help both themselves and the industry by variety control.

Commercial and industrial users of stationery either :

(1) Refer to a suppliers catalogue and choose what they want ; or

(2) Order what they require by creating their own specifications or by making reference to national or international standards.

From the industry's point of view a national or international standard is to be preferred. However, "Variety Control begins at Home"—a statement that I wish to develop.

Any organisation wishing to adopt a variety control programme must first establish and organise its existing variety before endeavouring to simplify and standardise. The key to this activity is classification and coding. A classification and coding of plain and printed stationery must follow the three operations of correct identification, systematical classification and significant coding. After all items of stationery have been classified and coded and a code book has been prepared, the controller of stationery is able to find quickly and with absolute certainty from a master file of coded stationery, all items having similar features.

As a result :

(1) All close similarities are revealed immediately ;

(2) Complete or near duplication is highlighted ;

(3) Reliance upon memory and misleading titles is eliminated ;

(4) If a suitable item of stationery or form design exists, the creation of an unnecessary new one is prevented ;

(5) If a new design has to be created it can often be adjusted to replace one or more existing and similar items, as well as fulfilling the new function ;

(6) When new multiple forms are created, existing forms can often be incorporated ;

(7) A full picture is obtained of types and sizes and simplification and standardisation action can be taken.

Such a systematically classified and coded stationery record forms the basis for a policy for the supply and stocking of "preferred" types, and for the elimination and disposal of superfluous "non-preferred" stock which would otherwise constitute a capital liability within the organisation concerned. It is seldom realised that the annual cost of holding stock amounts on average to 20 per cent or even 25 per cent of the value of the stocks held. Clearly it is in the consumer's interest to control variety.

Below there is an extract from a simplification and standardisation case history showing the elimination of unnecessary variety of printing and writing paper sizes of an industrial consumer.

Elimination of Unnecessary Variety of Printing and Writing Paper Sizes

1. Prior to Classification

1. 9 in × 11 in	13. 20 in × 25 in	25. 25 in × 40 in
2. 11 in × 33 in	14. 20 in × 29½in	26. 25⅝in × 39½in
3. 12 in × 30 in	15. 20 in × 30 in	27. 25½in × 39½in
4. 14½in × 22½in	16. 21 in × 30 in	28. 26 in × 40 in
5. 16½in × 21 in	17. 21 in × 33 in	29. 26½in × 26½in
6. 17 in × 27 in	18. 22 in × 25 in	30. 27½in × 39½in
7. 17½in × 22½in	19. 22 in × 29 in	31. 28 in × 35 in
8. 18 in × 23 in	20. 22 in × 30 in	32. 28½in × 34 in
9. 18 in × 30 in	21. 22½in × 28½in	33. 29½in × 40 in
10. 18½in × 27½in	22. 22½in × 35 in	34. 30 in × 45 in
11. 19 in × 20 in	23. 23 in × 36 in	35. 36 in × 46 in
12. 19 in × 24 in	24. 24½in × 34½in	36. 30 in × 40 in

Thirty-six sizes (100 per cent)

2. After Simplification

Sizes	1	2	3	4	5	Total
	in	in	in	in	in	
Single ...	—	—	16½ × 21	18 × 23	20 × 25	3
Double ...	17 × 27	20 × 30	21 × 33	23 × 36	25 × 40	5
Quad... ...	—	30 × 40	—	—	—	1

Nine sizes (25 per cent)

3. After Standardisation

1. Quad Sizes :
27in × 34in 33in × 42in 40in × 50in
30in × 40in 36in × 46in
Five sizes (14 per cent)

2. Equipment for cutting Quad size in single and double sizes as and when required.

V. H. MANSELL

E. G. Brisch and Partners Ltd.,
London, S.W.1.
October 17, 1961.

Books just published

Irrigation and Climate : New Aids to Engineering Planning and Development of Water Resources

250 *pages. Illustrations. Tables.*

Publisher : Edward Arnold (Publishers), Ltd. 1961. *Price* £5

by HENRY OLIVIER, C.M.G., M.Sc. (Eng.), Ph.D. (Eng.), M.I.C.E., F.A.S.C.E., M.Soc.C.E. (France), M.(SA)I.C.E., M.Rhod.I.E., F.R.Met. Soc.

This book aims to give engineers and agriculturists simple methods for estimating quantities and times of crop water requirements in different localities. The book also gives an extensive bibliography taken from such allied fields as soil science, agriculture and meteorology. Chapter headings include outlines of the problem, review of the literature, development of methods for estimating basic monthly crop-soil requirements, meteorological considerations, irrigation studies, losses from marshes and the water requirements of wetfoot crops, and a summary of conclusions with reference to application of formulae and possible future lines of research. Also included are conversion factors, a bibliography and an index.

[Reply Card No. 1237]

Automatic and Remote Control

Proceedings of the First Congress of the Inter-International Federation of Automatic Control (I.F.A.C.), Moscow, 1960.

4 *volumes, paginated separately. Diagrams.*

Publisher : Butterworths & Co. (Publishers), Ltd. 1961. *Price* £45 *the set.*

Edited by J. F. COALES.

These four volumes contain all the papers contributed at the congress, and are divided into three main parts, theory, components, and applications. Group one (theory) contains papers on linear, continuous non-linear, discrete, optimal and self-adjusting systems ; statistical methods of investigation, theory of structure and signal composition, special mathematical problems, simulation and experimental methods, and terminology and education. The group on components is divided into electrical simulation, remote and supervisory control components, pneumatic components and computing devices, automatic control instruments and devices. The last group (applications) contains sections on automation in metalworking, electrical power systems, transport, industrial processes, chemical and oil industries and metallurgical processes, automatic control of thermal and nuclear power, and automatic electrical drives and machines. The introductory speeches are reproduced in volume one. All volumes have a complete list of contents for the set, and these are printed in English, German, and French in each case.

[Reply Card No. 1238]

Experimental Methods in Combustion Research; a Manual

300 *pages. Diagrams.*

Publisher : Pergamon Press, for and on behalf of Advisory Group for Aeronautical Research and Development, North Atlantic Treaty Organisation. Price £5 5*s.*

Edited by J. SURUGUE

This manual is issued in the form of a loose-leaf binder and it is intended to be kept up-to-date by future supplements. It consists of contributions from research workers who have specialised in a particular technique and the loose-leaf form is stated to have been adopted to enable new developments to be reported as soon as possible. The Editor is the Directeur Scientifique de l'Energie et Propulsion at the French Office National d'Etudes et de Recherches Aéronautiques, and of the eleven papers currently available six are in English and five in French.

[Reply Card No. 1261]

Engineering Science, Vol. 1

192 *pages. Diagrams.*

Publisher : English Universities Press Ltd. Price 9*s.* 6*d.*

by J. D. WALKER, B.Sc.(Eng.), M.I.Mech.E.

This is the first of two volumes intended to cover the engineering science requirements of the new General Course in Engineering. It is a modification of *Mechanical Engineering Science,* Vol. 1, omitting certain work in the section on heat and adding an introduction to electrical engineering science. There are chapters on the elementary principles of the study of force, stress, work, energy and power, friction, machines, heat, and electrical technology. There are exercises with answers, and a chapter on writing up experiments. Some mathematical tables are included and there is a subject index. The author is the Head of the Department of Civil and Mechanical Engineering at the Huddersfield College of Technology.

[Reply Card No. 1268]

Railway Snowfighting Equipment and Methods

95 *pages. Illustrations. Diagrams.*

Publisher : The author, Hadfield, Hyde, Cheshire. Price 15*s.*

by G. RICHARD PARKES

The author discusses the disruption caused by snow of railway services in this country, then comments on specific equipment used for snowfighting. The book is lavishly illustrated with photographs of railway chaos and equipment in action, and there are some simple diagrams of equipment.

[Reply Card No. 1264]

Trade Unions, a practical approach

73 *pages*

Publisher : Longmans, Green and Co. Ltd. Price 6*s.*

by R. B. DAVISON

This approach to trade union education was first used by the author when he was on the staff of the then University College of the Gold Coast. It is an attempt to educate trade unionists in note taking, committee procedure, speechmaking, correspondence, &c. The method used is the setting of specific tasks based on different aspects of trade union work with a key to the way these jobs should be attempted.

[Reply Card No. 1266]

Application of Digital Data Recording*

By R. C. DEBNAM, A.M.I.Mech.E.

Two techniques used at the National Physical Laboratory in the calibration of secondary standards of load are described. The secondary standards are in the form of electrical resistance strain gauge load cells and are calibrated by reference to the 50-tonf deadweight standard machine at Teddington. Certain electrical measurement problems which arose in the application of these techniques are also discussed. A digital data recording system which has given a satisfactory solution to these problems is described; this system will record measurements of output voltages of load cells, over a range 0 to 26,000μV with a repetition of ±3μV. These measurements may be made either manually, or automatically at a rate of one per second.

LOAD measuring devices of magnitudes up to 50 tons-force (tonf) are calibrated at the National Physical Laboratory by means of two standard deadweight machines. Load measuring devices of capacities greater than 50 tons-force are calibrated by comparison with secondary standards of load, and for calibrating compression load measuring devices these secondary standards are usually load cells which incorporate electrical resistance strain gauges. These secondary standards of load are calibrated with reference to the primary standard of load, provided by the deadweight machines, by means of two separate techniques.

The first technique is to employ a load cell which incorporates a number of columns arranged in parallel. These columns are as identical as possible with regard to dimensions, material and heat treatment. Each column consists of a Ni-Cr-Mo alloy steel bar of round or octagonal section and of suitable dimensions for the load to be carried. To each column wire resistance strain gauges are bonded, and these are wired to form a Wheatstone bridge network. Strain produced by loading the column brings about a change in resistance of the bridge circuit. If the bridge is energised, this change in resistance appears as a voltage change across the bridge circuit and may be measured on a suitable potentiometer; thus it becomes a simple operation to apply a load to a column and express that load in terms of a voltage. According to the maximum strain associated with full-load on the column, the maximum voltage change will be up to 26,000μV for a 10V d.c. supply. After individual calibration, by a series of loadings in the N.P.L. 50-tonf standard deadweight machine, the columns are assembled between end platens to form a composite unit, so that they share almost equally any load to which the unit is subjected. Fig. 1 shows the most advanced example of this multi-column type of load cell as used at N.P.L.; the cell consists of nine 50-tonf columns giving a maximum load capacity of 450 tonf.

Referring to the figure, it should be explained that each individual column has a steel ball located in a spherical recess in its upper end; each ball in turn supports a loading cap, similarly recessed on its lower surface. The columns, arranged in groups of three, support, by means of their loading caps, three intermediate platens. Each intermediate platen has a steel ball recessed into its upper surface, each ball supporting a further loading cap. These three loading caps further support a robust platen of large diameter which forms the upper loading surface of the cell. This arrangement of columns produces an almost uniform kinematic condition of loading.

It will be seen that, mechanically, these columns are in parallel and it has been the practice to arrange switching of the bridge circuits so that the output voltages could likewise be joined in parallel electrically. It is therefore possible to compare the average output voltage measured from the nine circuits for a given applied load with the average arithmetical output voltage calculated from the readings obtained during the calibration of the individual columns at one-ninth of the total applied load. This method of measuring has serious weaknesses in that, if the bridges are not carefully balanced with respect to common supply

Fig. 1—Multi-column type of load cell of 450 tons-force maximum load with cover removed

points, current flow between bridges will result when the bridges are linked in parallel. Again, current circulates between the bridges if the mechanical positioning of the load to be measured results in some columns bearing more than their equal share of the total load. Further, if one bridge open-circuits it might remain undetected for a considerable period of time. Thus it becomes desirable that the output voltage of each bridge be always individually measured either simultaneously or in rapid sequence, an impracticable feat if vernier potentiometers are used to measure the bridge outputs.

In the second technique for calibrating secondary standards of load, three separate load measuring devices of known calibration are arranged, so as to share the load applied to a fourth device. This method is used at N.P.L. for standardising secondary load measuring devices of up to 1000 tonf in compression from standards of 50 tonf capacity which have themselves been calibrated in the 50-tonf deadweight standard machine. Three 50-tonf proving rings are first used to calibrate, in turn, each of three 135-tonf load cells. The proving rings are placed symmetrically on the platen of a compression testing machine, the rings supporting an auxiliary platen on to which is placed the load cell to be calibrated. Thus the load applied to the "pyramid" is determined from the summation of the loads as measured by each proving ring. After calibration the three 135-tonf load cells form the base of a new "pyramid" and are used to calibrate, in turn, three 400-tonf load cells which, finally, are used to calibrate a 1000-tonf load cell.

The commercially obtainable type of load cell used at the N.P.L. in this method of "build-up" consists of a single column on which strain gauges are bonded and connected to form two completely independent Wheatstone bridge circuits; thus, ideally, eight observations would have to be made simultaneously if both circuits of each of the four load cells of a "pyramid" were in use. As the amount of equipment available, and, in particular the number of observers available, do not permit simultaneous readings, a method permitting readings to be taken in rapid sequence and repeating them in reverse order immediately, had to be adopted.

Both techniques, therefore, demand a means of both making and recording a rapid sequence of readings, and only an electronic method is capable of meeting such demands. A suitable method using digital data recording has been developed at the Laboratory in collaboration with Solartron Research and Development Ltd., and is described below.

The range of the output voltage to be measured was from zero to a maximum of 26,000μV d.c., corresponding to the range zero load to full load on a column or unit load cell, and to obtain a parity of measurement with the vernier potentiometer previously used, a resolution of 1μV and repetition of reading of ±3μV were desirable. At the time the new method was first considered, digital voltmeters capable of five-window display did not exist, and available instruments of four-window display were only capable of millivolt performance. Discussion with representatives of firms manufacturing such equipment brought forth a suggestion that accurate "backing-off" of signal could be obtained by means of a circuit in the form of a potentiometer. Thus the bulk of the d.c. signal would be cancelled; the residual voltage would then be amplified by means of a fixed gain amplifier and displayed on a digital voltmeter giving both the very long scale required and the necessary resolution. It was appreciated that such a system working at low orders of voltage might be very prone to noise and spurious signals of μV level.

A backing-off circuit was developed at N.P.L. which consisted of a potentiometer network, energised by a voltage derived from a dry cell, this voltage being adjusted by reference to a standard cell. Such a circuit permitted the use of components having low impedance relative to the input impedance of the following d.c. amplifier.

Two prototypes were constructed to determine suitable layout and values of the

* Communication from the National Physical Laboratory

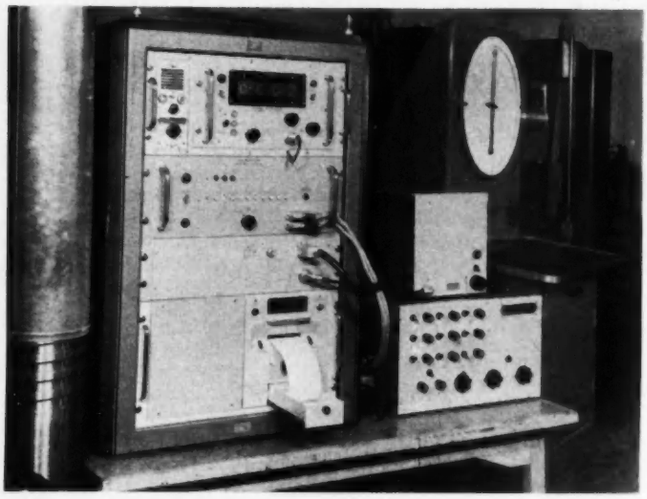


Fig. 2—Digital data recorder

components and also to assess noise and repetition. From the encouraging results obtained a simplified but more sophisticated unit was designed, being combined with a control box unit and made remote from heat sources which would occur within the main equipment cabinet. Meanwhile an order had been placed with Solartron Research and Development Ltd., to develop and supply suitable data recording equipment. The complete instrument is shown in Fig. 2 and the line diagram (Fig. 3) depicts the main components of the system in the order of operation. It will be seen from the following description that the system consists of standard items suitably modified for low voltage operation.

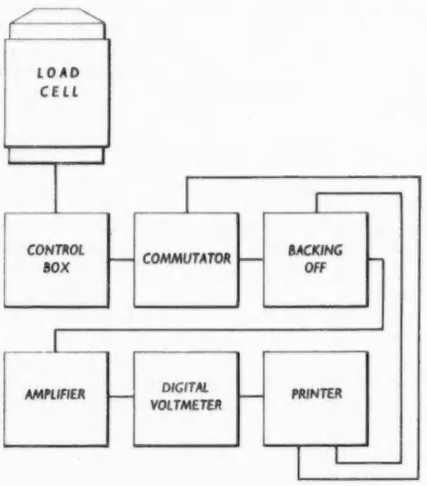


Fig. 3—Layout of components of digital data recorder system

Control Box

This has been developed to permit the attachment of either the 450-tonf load cell consisting of nine bridge circuits, or of up to eight bridge circuits of any four single-column load cells. Connection is made by means of multi-way sockets at the rear, together with other sockets for applying the energising 10V or 6V supply for the various cells. In addition, certain sampling points are provided, mainly to determine the energising voltage, whilst a number of helipot resistances, provided to balance under no-load conditions each individual bridge circuit, protrude from the front cover. Within the box the inputs are wired so that incoming signals are routed to the appropriate channels; at the same time the incoming signals are repeated a second time in reverse order, i.e. the signal on channel 1 appears again on channel 18, likewise 2 on 17, &c. Thus a total of eighteen load cell signals are passed to the commutator. The commutator has available a total of twenty-five channels and it has, therefore, been found necessary to superimpose a signal approximately equal in magnitude and of the same polarity as the incoming load cell signals, on the remaining seven spare channels and on to any other channel not in use. Thus a similar voltage will be presented on each channel to the opposite polarity backing-off voltage imposed later in the sequence of operations. A multi-way cable transfers all signals to the commutator.

Commutator

Controlled by transistorised electronics, the commutator is of the sequential relay type. Normally designed for fifty channel operation the commutator was modified to twenty-five channel operation only, permitting screening which reduced noise to the order of 2μV.

The commutator has three modes of operation, selected by means of a switch; manual, single scan or automatic. The manual position permits the selection of any one of twenty-five channels at random by push button command. The single scan position permits one complete scan in sequence of all channels, whilst the automatic position scans in sequence continuously until commanded to stop. Both the single scan and automatic modes have an operating speed of one sample per second, this being derived by counting-rings of transistors, counting 50 c/s derived from the mains.

The selected channel voltage is next passed to the backing-off circuit; in addition, channel identification is passed direct to the printer.

The Backing-off Circuit

The circuit used is shown in Fig. 4. The main elements are the precision decade resistance units from which the opposing signal is derived. Other precision fixed resistances are used, together with a standard cell and an oil damped galvanometer; adjustments and trimming of the various parts of the circuit are effected by helipot resistances.

The main decade resistance units are ganged to the unit which selects the dummy signal to be superimposed on to any channel not in use, and are also ganged to a rotary switch which feeds information of the backing-off setting to the printer. Thus by this ganged switch system three operations are

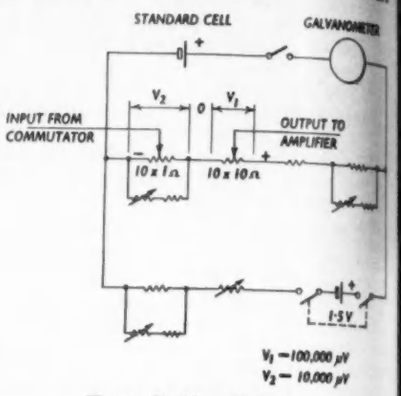


Fig. 4—Backing-off circuit

completed simultaneously, and the main function of "backing-off" is achieved in 1000μV steps to a maximum of 26,000μV. The residual signal, less than 1000μV if the pre-selection of the backing-off voltage has been correctly made, is passed to the amplifier.

The Amplifier

The unit is a stable, low drift, wide band d.c. amplifier, designed for amplification of low level signals. The high accuracy is obtained by using a large negative-feedback technique to provide precise, stable gain conditions. Variable gain adjustment is available in steps, and also fine adjustment is provided about each step. Checking and adjusting is carried out by passing a nominal signal, derived from the backing-off circuit, through the amplifier. The amplifier normally operates at a gain of 1000 ×, passing the amplified signal to the digital voltmeter.

The Digital Voltmeter

This voltmeter is an analogue-digital converter of the binary sequential trial type, in which the voltage to be measured is compared with an internal voltage. This internal voltage is produced by switching currents through precision resistances so as to represent binary digits, and acceptance or rejection of the digit depends on whether the current through the resistance is smaller or larger than the current resulting from the input voltage. The final digital output is obtained by considering each digit which has been in turn tried and accepted. This switching operation is achieved by relays interconnected to give a decimal output for the indicator. The indicator is a four digit projection display, polarity being indicated by red or black background to all digits displayed. To obtain 0·1 per cent accuracy an in-built standard cell is used as a reference.

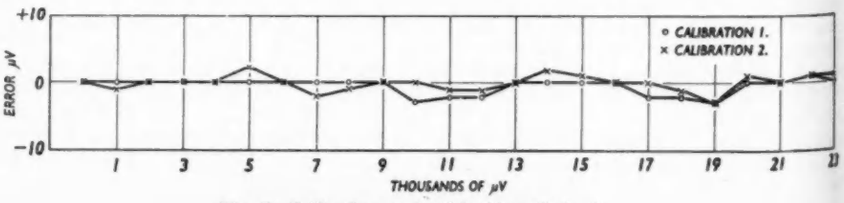


Fig. 5—Calibration graph of backing-off circuit

Fig. 6 — Technique of "build-up" of secondary standards of load using a number of separate load cells

potentiometer adjustment being provided to standardise the instrument. The voltmeter may be used to continuously monitor the signal, variation causing the reading to change; the amount of variation to initiate a change of reading may be adjusted, by the use of "dead-zone" facilities, to 0·5, 1, 2 or 5 digits as required. A second mode of operation of the voltmeter is that of "sampling"; at command, the value of the voltage measured appears in the windows and remains until the command button is again pressed. This operation can be made remotely in this particular equipment, command being made by the commutator when the single scan or automatic modes of operation are in use. Whichever "mode" of operation is used the voltmeter takes 280 milliseconds to change reading, regardless of the amount of the change.

A socket on the voltmeter enables the digital display to be transmitted to the printer.

The Printer

This is an eleven-digit in-line printer with transistorised electronics. Each of the eleven print wheels carries engraved digits 0–9, a hyphen, an asterisk and a blank, each wheel being mounted on a common rotating shaft. The drive of each print-wheel is by friction and the wheel is stopped by a solenoid-operated pawl engaging in a ratchet moulded into the print wheel. Attached to each print wheel is a wiper-contact which passes over a printed circuit board giving an electrical indication of the position of each print wheel. Thus, when the desired character is in the correct position the solenoid is de-energised causing the pawl to drop into the ratchet and arrest the wheel. At the appropriate moment the command is given to print, this being achieved by a hammer striking the paper against the print wheels, an ink ribbon being interposed. Both the paper strip and ribbon are automatically advanced. The printer has a maximum rate of printing of five lines per second, but in this particular system, the rate of printing is restricted to one line per second.

Extensive tests have been made on some of the individual components of the system, but to obtain a realistic assessment of accuracy, calibrations have been made of the equipment overall. A series of nominal voltages, known to $\pm$ one part in 100,000, have been measured by the system, the error after "backing-off" appearing on the digital voltmeter, and these calibrations indicate that the system is capable of making measurements to a maximum of 26,000μV to within $\pm 3\mu$V. A curve, typical of such a calibration, is shown in Fig. 5. The effect of noise is considerably less than was anticipated due, no doubt, to a high degree of screening within the commutator and extra filtering within the digital voltmeter.

Overall Performance of System and Load Cell

Having determined that the system was satisfactory, a number of calibrations of the 450-tonf load cell were made in the 50-tonf deadweight standard machine. Previous calibrations, using a vernier potentiometer, had shown that loads measured by the cell (the bridge circuits of the nine columns in parallel to each other) were correct to better than $\pm$one part in 500 ($\pm 0{\cdot}2$ per cent). However, calibrations made with the data recorder have shown the load cell to be better, a determination of load applied to the cell being possible to $\pm$one part in 1000 ($\pm 0{\cdot}1$ per cent) within the normal working range of the cell, i.e. from one-fifth full load to full load.

Fig. 6 shows the digital data recorder being used with a number of separate load cells, in the alternate technique of "build-up" of secondary standards of load.

The work described in this paper forms part of the research programme of the National Physical Laboratory and is published by permission of the Director of the Laboratory.

Engineering Teaching in the Universities

By HUGH CLAUSEN

PROFESSOR BAKER, speaking at a dinner in London last year, was reported in *The Times* to have said that in the last ten years, seventeen (I think) professorial chairs in engineering had been awarded to men from the engineering department of Cambridge University. This is a very remarkable achievement; and one can almost sense a very justifiable note of pride in the speaker's voice.

On the other hand, it does "give one furiously to think." Most of these men would not describe themselves as engineers; and even if they did, they would hardly be so described by others. They are physicists, Professors of the mechanical sciences. Some further reflection seems to be needed here.

Engineering is not a science, or even an applied science. It is an art, to which many sciences make their contributions. It is an art in which the eye, hand, and brain must work in unison; the work of each reacts on, and helps in the development of, both the others.

The great creative men of the eighteenth and early nineteenth centuries—those who left the strongest mark on the pattern of our civilisation—rarely had any university background. They were mainly the product of the older master/apprentice relationship; not in its present emasculated form for training craftsmen, but for bringing up men to assist—and in due course replace—the master.

Few—if any—of the exhibits at, or even the unique building of, The Great Exhibition of 1851 owed anything at all to university thought, tradition, or background. They were the products of this older master/apprentice system, which was already in decline at the time. It has now disappeared completely, and nothing has, as yet, taken its place.

This, I believe, is the prime cause of our technological backwardness. Most other nations seem to have replaced it by something more effective than we have, without in any way compromising their university structure, or giving rise to any educational disturbance.

Now a science may be studied in a university where a scientist may find his life's work, and so give to his students something of the old master/apprentice benefit. The same applies to historical or literary studies, and other more customary university activities. Not so with an art. It hardly seems possible to pass on an art from one generation to another without some personal master/apprentice relationship.

Even in the old established faculties of The Church, Medicine, and Law, the universities only seem able to give a preliminary rather than a professional training. The atmosphere of scholarship and learning seems ill suited as an introduction to the creative aspects of either the industrial, or the fine, arts; though critical or analytical aspects may gain from it.

A professor of engineering nowadays is usually not an engineer at all, but a professor of the mechanical sciences; and this tendency is increasing. Whether he can provide his students with a good introduction to the art of engineering will depend mainly on the character and previous experience of the men concerned.

A university discipline cannot create talent, any more than an industrial one can. Properly applied it can help it to develop; but it can equally well frustrate, or even destroy, it. The professor of the mechanical sciences is well placed in a university, but it looks as if the professor of engineering should be functioning in a different institution.

Oxbridge seems to have been, throughout most of its history, a vocational training establishment for the more highly esteemed occupations. However, as the criteria of relative esteem were largely determined by ex-Oxbridge students, the problem was simple.

Oxbridge went on, in its somewhat

dilettante way, believing that the activities with which it did *not* concern itself—and on which the entire economy of the country (including itself) depended, were being properly dealt with elsewhere.

This is no longer the case. If we are to survive as an independent nation, the universities, as a large and rapidly increasing component of the social structure face a very definite and very serious choice. Many of them must take under their wing, and modify their internal structure so as to be able to deal properly with, the creative industrial arts—of which engineering is one.

As an alternative, they must give every possible support and encouragement towards the development of other establishments where these arts can be dealt with up to the highest levels.

In the past the Oxbridge attitude in these matters has been more than unhelpful. It could well be described as helpless! After a hundred years of opposition the beginnings have been launched, in the form of the C.A.T.s. There is now the chance—if the older universities will collaborate—of building up something of what is needed to fill the gap.

There is a danger though. At present the C.A.T.s seem rather to be apeing the universities in the type of courses, teaching methods, and staffing. Success depends on their being something different.

In the issue of *Nature* of April 8, 1961, there were two very notable articles on these matters ; one was a leading article, the other was by Dr. S. C. Curran, F.R.S., Principal of the Royal College of Science and Technology, Glasgow. Both deal with building up higher educational establishments of the type needed ; not restricted to scholarship and learning but capable of dealing with the professions and the industrial arts.

A beginning has been made in Glasgow, and elsewhere ; and provided that the older universities adopt a co-operative rather than an obstructive attitude we should before long be well on the road to making up for a hundred years of neglect.

As G. L. Payne says, reviewing our current educational developments : "A share of responsibility for the delay must also be laid at the door of some of the spokesmen for the universities, whose thinly veiled, though stoutly denied, jealousy of their university prerogatives, and whose academic snobbery towards the technical colleges compounded the inevitable differences of opinion, and made agreement on a course of action more difficult than it need have been."*

And, as *The Times* review *Technology* said : "The C.A.T. scheme will have failed unless the man or woman who now teaches in a university feels it in no way a loss of status or conditions of work if he or she transfers to an advanced college."

These matters may be—probably are—the determining factors in our future economic situation, in fact, in our very existence as an independent nation.

Research and Electrical Transmission

I.E.E. SUPPLY SECTION CHAIRMAN'S ADDRESS

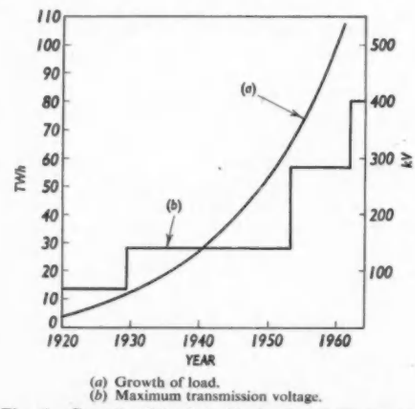
The chairman's address to the Supply Section of the Institution of Electrical Engineers was delivered in London on October 18 by Dr. J. S. Forrest† and is reproduced below. Dr. Forrest showed how the rapid development of large electricity supply systems depends upon transmission research, with particular reference to overhead lines. He referred to some of the research programmes which the electricity supply industry has initiated in this country, looking towards anticipated transmission requirements about ten years ahead.

Development of Electricity Supply

LET us look at the development of electricity supply in this country during the last 30 years or so, because such information provides the basic background for our research needs. Fig. 1 shows the growth of load and illustrates that the demand doubles every decade. It also shows the maximum transmission voltage in use at the time. The voltage has had to be increased in steps of roughly 2/1 to enable the system to handle the increased load. Looking back to the past it may be thought that we were not bold enough and that steps of 3/1 would have been justified, but it is not so easy to take such decisions in the present. We have now decided that the next step shall be 400kV. Should it have been 500kV or 650kV ? Will the load go on increasing at the same rate ? Will nuclear power or thermonuclear power, or some new means of generating electricity, make local generation economic and render the transmission system redundant ?

It is well known that the load doubles every ten years, but Fig. 1 also illustrates a fact which is not so well known, namely that, broadly speaking, the transmission voltage has been doubled every 20 years. This is what one would expect, as the load-carrying capacity of the system is proportional to the square of the voltage, and it indicates that our choice of voltage through the years has not been far wrong. On this basis we shall require 550kV in about 1980.

This is the picture which provides the raw material for our transmission research. It may take ten years from the commencement of a research programme until the results are embodied in practical operation, so that, to be effective, research should be ten years ahead. We have always tried to study transmission systems at about twice the present maximum operating voltage. Thus we were carrying out research at 264kV in 1938, at 380kV in 1953, and arrangements have now been made for work on 600–700kV lines. The increase in our facilities necessary to deal with these high voltages is of interest. H.V. research was started by the C.E.B. at Croydon in 1934 with an outdoor testing station having a maximum voltage of 85kV. In 1950, the Leatherhead h.v. laboratory of the B.E.A. was completed with 250kV a.c. and 1·4MV impulse plant. A new Leatherhead h.v. laboratory has been built recently by the C.E.G.B. which provides facilities for research up to 4MV impulse, 1·2MV a.c. and 1MV d.c. A new high-voltage experimental line supplied from the laboratory will enable line problems to be investigated up to 500kV to earth. In addition, an insulator testing station to investigate performance under coastal conditions at voltages up to 375kV a.c. to earth, and 110kV d.c. has been established at Brighton.



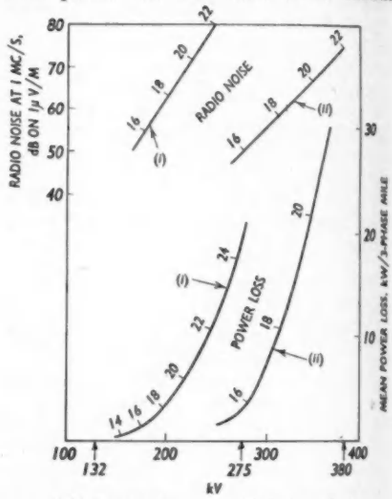
(*a*) Growth of load.
(*b*) Maximum transmission voltage.

Fig. 1—Growth of load in England and Wales and maximum transmission voltage

H.V. Overhead-Line Conductors

The increase in line voltage leads to an increase in the voltage gradient at the conductor surface, and if this reaches a value in the neighbourhood of the breakdown strength of air, 21kV (root mean square) per centimetre, a corona discharge occurs which leads to a loss of power.

In addition, and this may be of greater importance, the corona discharge generates radio noise which can interfere with the reception of broadcasting and television. Both power loss and radio noise increase rapidly with the gradient (Fig. 2). Fortunately there is an elegant solution to this problem—the use of "bundle" conductors suggested by Markt and Mengele in 1932. By using a bundle of two, three, or four conductors the surface gradient can be reduced to such an extent that power loss and radio interference do not present serious problems. It is interesting that many transmission engineers were slow to accept bundle conductors, and it was not until about 1950 that they were generally recognised as being the best system for voltages of 300kV and above. Many questions like this have initially to be decided on the opinions of experienced engineers—when they are right they show good judgment and when they are wrong it is prejudice! Fig. 2 brings out two interesting properties of bundle conductors.



(i) Single conductor. (ii) Twin conductor.
The figures on the curves are surface gradients in kilovolts (root mean square) per centimetre.

Fig. 2—Mean corona power loss and radio noise under the line for single and twin 0·175 square inch s.c.a. conductors

For the same voltage, the surface gradient of the twin conductor, and the power loss, is much lower than for the single conductor. On the other hand, for the same gradient the

*Britain's Scientific and Technological Man-power. By G. L. Payne, Oxford University Press

† Director of the Central Electricity Research Laboratories.

power loss for the twin conductor is greater ; it is proportional to the square of the total surface areas of the conductors.

Similarly the radio noise for the same voltage is less for the twin conductors owing to the lower surface gradient, but, curiously enough, the radio noise for the same gradient is about 5dB less for twin than for single conductors. This favourable feature of bundle conductors has not yet been satisfactorily explained.

In addition to the reduction in surface gradient the bundle conductor has a smaller reactance than the equivalent single conductor, and this is often advantageous. The increase in load-carrying capacity of transmission lines resulting from high voltages and bundle conductors is quite dramatic, as shown in Fig. 3.

Mechanical Design of Overhead Lines

The electrical design and performance of overhead lines has been the subject of a great deal of research, but very much less attention has been devoted to mechanical design. The mechanical design of overhead lines presents many important problems, and there is scope for much interesting research on this subject. Some topical problems on which work is at present in progress are discussed briefly below.

Conductor Spacers.—The component conductors of a bundle need to be kept at the proper distance apart by a spacer, and this apparently simple device gave a great deal of unforeseen trouble. After a few years, the vibration and movements of the conductors damaged the spacers and it was necessary to replace them with improved designs. Accordingly a machine was built to subject a spacer to the types of movement experienced in service, but at a higher repetition rate, in order to obtain data quickly on the likely behaviour of a given design on the transmission system.

The machine applies three main movements, all independently adjustable in amplitude, namely : relative vertical movement of conductors ; relative longitudinal movement of conductors ; and relative angular movement of conductors, such that the spacer is subjected to a torque along its axis.

The machine is fitted with a servo-control mechanism which enables it to be set up and left unattended whilst the spacer is subjected to the equivalent of many years' service in a few hours.

It is necessary to ensure that all spacer designs are tested under equally arudous conditions. This is not easy because one type may be free to move in a particular plane, while another is relatively rigid ; attempts to compare these two designs by subjecting them to identical movements would be misleading. Accordingly, the static load/deflection characteristics of the spacer in the vertical, horizontal and torsional planes are measured first. The machine is then adjusted to subject each spacer to deflections corresponding to given static loads.

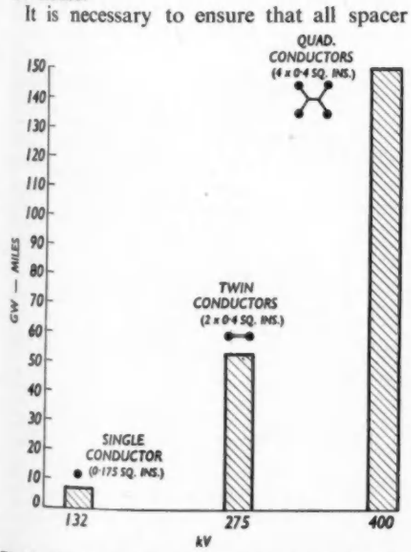


Fig. 3—Load-carrying capacity of overhead lines with 0·175 square inch conductor, twin 0·4 square inch conductor and quad 0·4 square inch conductor

The machine has successfully reproduced the kind of mechanical wear known to occur in service. It is now being used to select replacement designs and to determine the relative endurance of new designs.

Oscillation of Overhead-Line Conductors.—The phenomena of vibration and oscillation of overhead-line conductors have been known for many years. Vibration, i.e. the small sustained relatively high-frequency oscillation, is easy to suppress with simple mechanical dampers. The slow large-amplitude oscillation (" dancing " or " galloping ") presents a much more difficult problem.

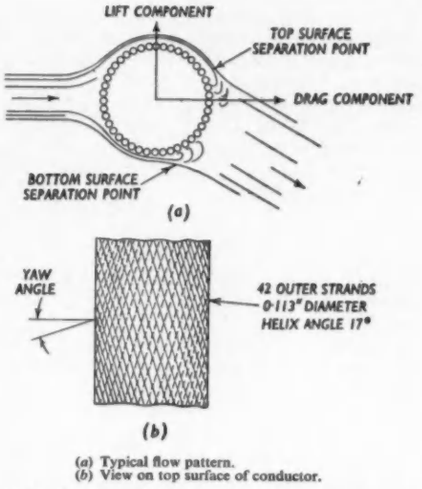
Until recently this type of oscillation was thought to be always associated with the formation of ice on the conductor. The ice alters the aerodynamic shape of the conductor so that a steady horizontal wind may lift the conductor and set it into oscillation at a frequency equal to some harmonic of the natural frequency of vertical oscillation of the conductor catenary. The amplitude is governed only by the material damping of the conductor and the associated mechanical components. Recently there has been evidence of the occurrence of oscillation when no ice was present on the conductor. In particular, this phenomenon has caused conductor clashing on the new 275kV crossing of the River Severn between Aust and Beachley, which has a span of 5310ft and 1·7in diameter conductors.

Records taken on the crossing indicate that, in addition to pendulum swinging of the catenary in the fundamental mode, two forms of vertical oscillation have occurred, each with a periodic time of about 8 seconds. Of these, the more dangerous, which has attained an amplitude of about 36ft, has nodal points not far distant from the suspension insulators. The other, and more common, form is usually associated with horizontal swinging, and has nodal points at mid-span and at the suspension points.

It has been established in a wind tunnel that at certain wind velocities and angles of yaw to the conductor a substantial lift force occurs, owing to the differential separation of the boundary layer around the stranded conductor (Fig. 4). Unlike " galloping," due to ice on the conductor, oscillations can be sustained only under gusting conditions. The wind records made on site have established that the wind directions and velocities when clashing occurred lay within the range which gives rise to lift. Mathematical studies, using an analogue computer, have established that the measured lift component could give rise to amplitudes large enough to cause clashing.

The aerodynamic lift can be reduced by using a conductor with a smooth cylindrical outer surface. It is not yet known whether this will be a complete cure but it should effect some alleviation, and as an experiment, P.V.C. tape is being applied to the conductors of one circuit of the crossing in order to establish whether the problem can be solved aerodynamically rather than mechanically.

This investigation has emphasised the need for a better understanding of the dynamics and aerodynamics of the suspended catenary.



(*a*) Typical flow pattern.
(*b*) View on top surface of conductor.

Fig. 4—Aerodynamic lift force on a stranded conductor

Non-Elastic Extension of S.C.A. Conductor.—It is well known that, after erection, a stranded s.c.a. conductor will stretch non-elastically, the sag and tension altering in consequence. This extension is due to the creep of the aluminium strands, and the bedding-down of the strands under tension. The phenomenon is difficult to deal with analytically because the amount of the extension depends upon such factors as the laying-up tension and temperature, the stress/strain characteristics of individual strands before and after load cycling, and conductor temperature during erection.

In order to ascertain by how much a given conductor, manufactured under known conditions, will extend after erection, a number of test spans are being erected at West Weybridge, so that the behaviour of selected conductors can be studied under carefully controlled conditions. Five span lengths have been chosen, ranging from 200ft to 250ft in length, each test length consisting of three 0·4 square inches s.c.a. conductors made by three different manufacturers. Continuous recordings will be made of conductor temperature and tension, wind and ice loading, and support deflection.

In addition, the field measurements will be complemented by constant load, constant strain, and load-cycling tests in the laboratory, using samples from the same drum as the conductor erected at West Weybridge. If a correlation between the field and laboratory measurements can be found, it will be possible to specify a tensioning technique, based on laboratory tests on samples from each batch of conductor, which will minimise resagging.

Foundation Design for Overhead-Line Tower.—The present method used for the design of uplift foundations is based upon an assumption rarely borne out in practice. The resistance of the foundation to uplift is taken as the weight of soil being uplifted together with that of the foundation, and it is assumed that the inverted frustum of a pyramid of soil is uplifted, whose sides diverge upwards from the base of the foundation at an angle of 30 deg. A figure of 100 lb per cubic foot is normally taken for the soil density.

When an existing line has to be removed the opportunity is often taken to test the foundations to destruction in order to obtain factual information on their strength, with the ultimate object of deriving a more precise method of foundation design. Two methods of test have been used. In the first, the tower is overturned by applying a load at bottom cross-arm level ; both tension and compression stub movements are recorded and tower-leg loads are measured using electrical

resistance strain gauges. Apart from the data obtained concerning the foundations themselves, these tests yield valuable information on the relative strengths of tower and foundation. For the towers tested so far, the tower legs failed by buckling immediately above ground level, although by the time this stage was reached, the tension foundations themselves had failed.

In the second method, the tower is dismantled and the strength of each footing measured separately. A 50-ton rig was designed for this purpose and has been used on various types of foundation, particularly on selected sites on the dismantled Staythorpe–West Melton 275kV line. Earth pressures were recorded using earth-pressure cells located around the foundations. This work is still in progress but the following broad conclusions may be drawn :

1. The volume of soil uplifted is often much less than that of the 30 deg. pyramid frustum.

2. The compaction of the backfill is often quite inadequate, and little uplift pressure is transmitted through the backfill/virgin-soil interface.

3. The shear strength of the soil, which is neglected in the design, does contribute to the strength of the foundation.

4. The suction or tension below the base of the foundation, which is neglected in the design, contributes up to 25 per cent of the ultimate strength.

Insulators

The original 132kV Grid system is a testimony to the experience and the foresight of the C.E.B. engineers and consultants who planned it. They appreciated that insulation was a difficult problem in this country, and they provided a degree of insulation which was generous by standards in other countries. However, they had no service experience in this country above 66kV and no research data to guide them, and, in the event, the initial insulation proved inadequate in industrial districts.

Accordingly research was initiated with the object of improving the insulation. Work started at Glasgow in 1930 with the help of the National Physical Laboratory and was subsequently continued at Croydon by the C.E.B., where it became apparent that the problem would be with us for a long time. It was soon appreciated that no reliable method existed of measuring the performance of insulators in polluted atmospheres, and so it was not even possible to select the best of available types. The first job was therefore to develop a measuring technique, and this provides a good example of the part that chance and the " prepared mind " plays in research. It was soon discovered that the leakage current of an insulator in fog takes the form of a series of self-extinguishing surges, but the electronic apparatus which can be obtained " off the shelf " to-day for counting impulses did not exist. Even a cathode-ray oscillograph was a rarity. At Croydon substation certain telephone apparatus was being installed at this time, and it happened that a telephone call counter was on the bench where the insulator measurements were being made. Someone connected it in the insulator leakage-current circuit " just for fun " and we found that it was ticking up the leakage current surges above a certain value and providing us with a very simple way of assessing the tendency of the insulator to flash over in fog. This technique has stood the test of time and is used by investigators in various countries to-day for insulator performance measurements. I wonder what the chances would have been of a committee of experts, even if backed by adequate funds, proposing such a method at that time.

With the help of this method we were able to select the best insulator (we did not have to design a new one) from the multifarious shapes and sizes which were all claimed to have special virtues. We were also able to formulate various design criteria, such as the minimum leakage-path length of 1in per kilovolt, which are now generally adopted.

An interesting example of different approaches to the same problem is provided by the adoption of Langstab insulators in Europe (Germany mainly), and cap-and-pin insulators in this country and the United States ; or by the extensive use of glass insulators in this country and the exclusive use of porcelain insulators for high-voltage lines in the United States. The protagonists of each type can always produce plausible reasons for its superiority. Langstab insulators are puncture-proof, but cap-and-pin insulators do not let the line down if the porcelain is fractured ; glass insulators do not required to be tested in service, but porcelain insulators do not shatter completely when the shed is damaged. One would imagine that for a given problem there is a " best " solution, but it is not as simple as that even when, as is not usually the case, carefully controlled comparative measurements are made. The truth of the matter is that the adoption of a given system or technique is often decided by national or local considerations, and it is then developed to a reasonably practical state and technical arguments are subsequently produced to justify it. Thus the Langstab insulator is a reflection of the very bad experience the Germans had with cap-and-pin insulators and also the shortage of metal in the war years. Similarly the ascendency of the cap-and-pin porcelain insulator in the United States is traceable to the fact that the Americans make very good cap-and-pin porcelain insulators but experienced trouble with glass insulators some time ago. The moral is that one should not copy other people's systems slavishly, but try first to see them against the national background.

Future Possibilities

I have dealt mainly with overhead lines because in the present state of technology they are undoubtedly the backbone of any high-voltage transmission system. Last year, Mr. Robinson, in his chairman's address, discussed the other components of a transmission system—cables, switchgear, and transformers—and he indicated some of the changes which might occur in the future as a result of developments in materials. He touched on superconductivity, and it is interesting to note that, since his address was given, a new discovery has been made in the Bell Telephone Laboratories which brings the practical application of superconducting materials much closer. Previously, superconductivity could not be usefully applied in any electrical machine because the superconductivity was destroyed by a magnetic field. Now a new material, a niobium-tin alloy, has been discovered which retains its superconductivity in fields of up to 100,000 G. Current densities of 100,000 A per square centimeter are therefore possible without copper losses, and the only problem is to cool the equipment to 4 deg. K using liquid helium. The fundamental physical barrier has been removed and only a technological problem remains to be solved before superconducting transformers and cables are developed. The transformer could be built without an iron core, and both copper and iron losses could be eliminated—this saving would, of course, have to be set against the cost of the refrigeration equipment. The superconducting cable involves a more difficult refrigeration problem, but it presents a most attractive possibility for a d.c. cable. With an a.c. cable advantage could not be taken of the very high current densities possible because of excessive inductive voltage drop in the cable. With direct current, on the other hand, there would be no inductive drop, and no resistive drop, so that long-distance high-power transmission would be feasible without high voltage. The high-voltage rectifying and converting equipment, would no longer be required; rectification and inversion could be carried out by low-voltage solid-state convertors.

Ripping Machine for Coal Mines

A ripping machine for cutting roadways now in prototype service in coal mines is based upon a design evolved by Mr. Peake and developed from the results obtained with a test rig made at the N.C.B. Central Engineering Establishment. In this article a description is given of the test rig and the Mark II machine designed and built by Joy Sullivan Ltd.

ONE of the problems in longwall advancing mining, which is the most commonly used system in this country, is the advancement of roadways at a speed commensurate with the rate of coal extraction by mechanised equipment and with the least possible interference with normal working. These roadways, at right angles to the working face, provide access for men and materials and for the removal of coal. They are usually made by blasting out the stone which is removed and packed behind the coal faces as they are advanced. This practice of blasting a roadway has a number of disadvantages—it is relatively slow and interferes with normal coal production, whilst blasting not only disturbs the surrounding strata, but gives an irregular roof and wall contour leaving large open areas to be filled behind the arch supports when they are erected.

Some plant has been introduced to speed this work of road advancement by disposing of the stone by mechanical means. More recently attention has been turned to developing cutting or ripping equipment for making a roadway to the required shape without need for blasting and at a speed commensurate with that of the advancing coal face. One such machine suggested by Mr. Peake, formerly area production manager No. 5 area, East Midlands Division, has been developed on the basis of work carried out with a special test rig by the Central Engineering Establishment of the National Coal Board at Bretby. A prototype of the new machine now undergoing field trials has been made by Joy Sullivan Ltd. and is illustrated, together with the test rig, on the next page.

Before proceeding to describe the test rig and the first Peake ripping machine it should be pointed out to those not familiar with mining practice that, as the roadway is made after the coal seam has been removed, the space left provides a floor and a clear space the height of the original seam in front of the machine. The machine, therefore, is designed

to cut a roadway of inverted " U " shape extending above a lip left in the strata over the removed coal measure.

The test rig was built to determine the possibilities of ripping rock with rotating cutter drums as they were traversed over an arc. It has a " T "-shaped base built up of steel sections: the beam forming the head of the " T " carries the ripping assembly and that forming the stem the drive and a rear jacking column.

Whilst the machine is working it is held firmly by a hydraulic jack extended from the rear column on to the roadway roof, and jacks at each end of the head beam which are extended up to lock under the face. An arch built up of two spaced sections on the front beam, forms an outer guide path for the carriage of a boom pivoted at the centre of the machine. This boom carries two rotary cutter heads projecting in front of the machine, one outside the arch and the other inside. An endless chain, coupled to the boom carriage on the arch, passes over rollers between the arch members and a sprocket on a shaft on the centre line of the machine. This sprocket shaft is driven by a five-cylinder hydraulic motor at the rear of the machine to traverse the boom carrying the cutter heads over the arch during the ripping operation. A five-cylinder hydraulic motor drives each cutter head which is fitted with a 27in diameter by 11in wide drum having forty-four picks round its circumference.

Trials were carried out with this machine, first in a gypsum mine, where the results were limited by the tenacious nature of gypsum, and then in cutting coal measure shale at Coppice colliery in the East Midlands Division. In the second trials the machine was installed in a cross cut in a 4ft seam where the ripping is a typical medium shale containing ironstone nodules and laminated with four ironstone bands from 1in to 3in thick. These second trials were arranged to measure the power requirements of the machine and the respirable dust concentrations produced by different types of pick. It was found that the amount of dust produced might impede the use of the machine and it was decided that higher pick penetrations might produce less dust. New open design drums were made having an overall diameter of 29¼in with an 18in face, and these drums were fitted with face picks to enable them to " sump " into a solid ripping lip—thus widening the scope of the machine for thinner seams. Despite the difficulties with dust, which were the main drawback of the machine, it was decided that its promise and speed were such that the design was well worth promoting. Following this decision and based upon the results obtained with the test rig a production machine was designed and manufactured by Joy Sullivan Ltd., in consultation with the Central Engineering Establishment. This machine includes provision for advancing itself, and its drums, equipped with sumping cutters, contain integral water sprays for dust suppression. It is designed to cut a road 13ft wide by 10ft high, for a final 12ft wide roadway supported by arch girders and work where coal has been removed on seams with a minimum height of 2ft 9in.

The machine is mounted on a fabricated steel skid base through which it can be moved and positioned using independent chains and haulage gear. Heavy slideways, integral with the base, guide and support a cutter head carriage assembly, which can be moved along its ways over a distance of 2ft 3in by double-acting hydraulic cylinders, at speeds up to 3ft per minute when advancing or 3·9ft per minute when retracting. Heavy plate frames at each end of the carriage support the bearings of a large diameter horizontal tube on the front of which the cutter boom is fixed. Supported on the rear frame of the carriage is the main drive for the cutter drums. This drive comprises a 60 h.p. motor, driving, through a fluid coupling and reduction gearing, a shaft passing through the centre of the horizontal tube. The boom carrying the cutters comprises a rigid bolted assembly of heavy plates enclosing the gearing driving the shafts of the three cutter heads at 40 r.p.m.

The cutter boom is traversed through its arc by two double-acting hydraulic cylinders. The hydraulic cylinder at the front of the carriage is connected between an arm fixed at the end of the main tube and the top of the boom. The other cylinder at the rear is pivoted on an arm extension of the carriage frame and its piston rod is coupled to an arm locked on the tube. The first part of boom movement is effected by extension of the front hydraulic ram. At the limit of this extension the second cylinder comes into effect to complete the traverse. These hydraulic cylinders are designed to swing the boom through 180 deg. in a time varying between two minutes and twelve minutes when ripping and return it to its starting position in one minute. A pump behind the main motor supplies pressure fluid at 1500 lb per square inch for the hydraulic equipment and all the controls are accessibly grouped on a panel on one side towards the rear of the machine.

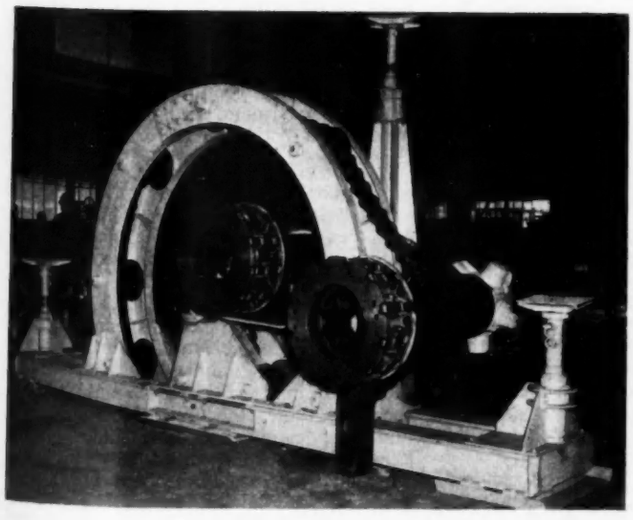
Heavy " A " frames extending up from the base and bridged at the top support two roof jacks connected by a girder; when extended this jack arrangement gives a positive loading between roof arch girders and the machine. This arrangement gives stability to the machine when cutting and assists in the setting of the roof girders.

The cutter drums have a diameter of 2ft 3in over the picks and up to seventy-three picks can be fitted in each. Internal water feed is provided to each drum and a supply of water is delivered to each pick for dust suppression.

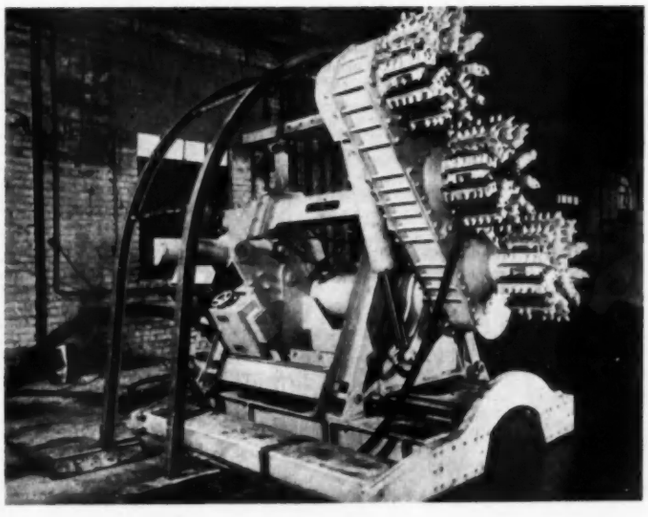
It will be seen that the machine base frame has a heavy " heel " extension on one side to take the reaction when cutting, whilst the other side leaves a clear width of about 3ft for the passage along its side for a gate conveyor belt leading from the coal face conveyor. An opening extending through the full length in the base of the machine enables a short conveyor or slusher ropes to be accommodated for the removal of dirt, for its dispersal by pneumatic stowing or other methods. Alternatively slusher packing of the cuttings into workings at the side of the roadway can be practiced, with the slusher ropes passing through the base of the machine on the front of which attachment points are provided for a slusher ramp and sheaves.

In an operational sequence the machine is positioned with the centre line of its drive on the centre line of the roadway with its boom lowered to the opposite side of the roadway to the gate conveyor and its drum faces just level with the face of the rip. The carriage is advanced or sumped to drive the cutters into the ripping lip to a depth of 12in and the boom then rotated in a vertical plane cutting over the whole face. The boom is then returned to its initial position and another cut taken. The carriage is afterwards retracted and the machine advanced for another cutting cycle.

The roof jacks with the girder support can carry the centre section of a three-piece arch to support the roof between the face of the rip and the last permanent setting. When a new arch is required to be set, the centre section is then already positioned for bolting of the side legs. With the profiled section of roadway cut the setting of the arches is thus a simple and rapid operation.



Rig to determine the possibilities of ripping rock with rotating cutter drums



Mark II ripping machine developed as a result of tests with experimental rig

Greenock Dry Dock

An important event for Clydeside occurred on October 16, when work on the Firth of Clyde Dry Dock Company's major dry dock project at Greenock was ceremonially inaugurated by Mr. J. S. Maclay, the Secretary of State for Scotland. Some details of the project, which comprises a dry dock 1000ft long by 145ft wide, a repair quay, a tanker cleaning depot, and appropriate shops and services, are given here.

CONSTRUCTION has now started at Greenock of a dry dock which, taking especially width into account, will be comparable in dimensions with only five dry docks in the world (namely at Camden, New Jersey ; Sasabo, Japan ; Sydney, Australia ; Cape Town, South Africa ; and St. Nazaire, France), when it is complete. Completion of the whole scheme, which includes a comprehensive group of dockyard developments, is scheduled within two-and-a-half years. The estimated cost is £4,250,000. Finance has been provided jointly by private enterprise, and by Government loan under the Local Employment Act. Work was inaugurated by Mr. J. S. Maclay, the Secretary of Sate for Scotland, on October 16. Both Mr. Maclay and Sir Gordon MacMillan, chairman of the promoting company, the Firth of Clyde Dry Dock Company Ltd., made speeches following the ceremony. Mr. Maclay referred to the efforts which had been made to diversify Scottish industry since the war, and then emphasised the " very first importance " still attached to the traditional industries, such as shipbuilding. The development he had inaugurated was complementary to the wholesale modernisation of shipyards on the Clyde ; it would accommodate 100,000-ton tankers and provide long-overdue tanker cleaning facilities. It would eventually give permanent employment to over 1000 men, he said. The principal statistics relating to the project are grouped in the accompanying table.

TABLE—*Statistics for Greenock Dry Dock Project*

Constructional quantities :	
Excavation for dock	500,000 cubic yards
Dredging in Great Harbour	500,000 cubic yards
Steel	7000 tons
Concrete	100,000 cubic yards
Data for Dry Dock :	
Clear length from gate to head of dock	1000ft
Extended length if required	1150ft
Width, cope to cope	156ft
Clear width between side walls	150ft
Clear width at entrance	145ft
Depth, top of keel blocks to cope	45ft
Depth, cope to floor at entrance	49ft 6in
Draft on sill H.W.O.S.T.	37ft
Draft on sill L.W.O.S.T.	27ft
Rise of floor	1 in 300
Time taken to pump dock dry without a ship at H.W.O.S.T.	2½ hours
Volume of dock at H.W.O.S.T.	$37{\cdot}5 \times 10^6$ gallons
Data for Repair Quay Berth :	
Length :	
Initial	800ft
Ultimate	1300ft
Draft :	
H.W.O.S.T.	37ft
L.W.O.S.T.	27ft
Cranage at dock :	
Two 15-ton	135ft radius
Two 60-ton	125ft radius
Auxiliary lifts :	
20-ton	185ft radius
5-ton, west side of dock	19ft radius
The 15-ton and 60-ton cranes are also used at the quay berth. The two 60-ton cranes are arranged to lift 120 tons in tandem using a lifting beam.	
Services :	
Compressed air	3000 cubic feet free air per minute at 120 lb per square inch
Grit blasting machines	Eight
Fresh water	180 tons per hour
Raw water	450 tons per hour (untreated fresh water for tank testing)
Salt water	2000 tons per hour for tank testing
Steam	18,000 lb per hour at 100 lb per square inch
Fire mains	700 g.p.m. (salt water) at 328ft head
Burning and cutting	Piped supply of oxygen and propane
Heavy fuel oil	6in main for heavy fuel oil from barge
Diesel fuel oil	4in main for diesel fuel oil from barge
Gas oil	Delivered by road tanker
Electric supply at dry dock and at quay :	1000kW, 440V, three-phase, 60 cycle a.c. 500kW, 220V, d.c. 250kW, 110V, d.c. 110V, a.c., three-phase 230V, a.c., two-phase

Design and Construction of Dock

The dock will be constructed mainly in reinforced concrete and is planned so as to be capable of extension from 1000ft to 1150ft should future trends so require. The walls are designed as cantilevers and the dock head as an arch spanning between the side walls. The floor of the dock is to be constructed in mass and reinforced concrete panels with an under-drainage system to neutralise the effect of uplift due to hydrostatic pressure from ground water when the dock is empty. From the exploratory borings already taken it is anticipated that the head of the dock and the entrance will rest on rock but the centre section will be founded on a valley of boulder clay running diagonally across the site. Piles will be driven through this boulder clay to the solid rock below.

A temporary cofferdam will require to be thrown across the entrance and the contractors are proposing using the permanent dock gate for this purpose.

A commodious subway will be incorporated in the walls running round the whole perimeter of the dock to carry the various services. An underground pumphouse some 60ft deep will be situated near the entrance at the north-east corner and will accommodate the three main dock pumps, ballast pumps, drainage pumps and other equipment. So as to keep the entrance of the dock clear of silt, one of the main dock pumps will discharge through a series of jets placed at intervals along the sill. Two of the main dock pumps can be reversed to fill the dock quickly.

On the dockside opposite the pumphouse an underground store will be constructed to accommodate chain blocks, shackles and other gear. Four main stairways will give access to the dock floor and there will also be a lift.

Ships will be handled into the dock by automatic leading-in gear controlled by winches at the head of the dock. A control tower will command the whole of the docking and undocking operations.

Operational Features of Dock

No side shores will be used when the dry dock is in use. Adjustable, pneumatically-powered side bilge blocks will be employed for docking vessels, giving free access to their sides for painting. Painting stagings will be self-propelled by compressed air motors. Side blocks are also to be fitted for tank testing. Fresh water will be available for hosing down hulls.

For hull repair work, the plating shop will be capable of dealing with plates up to 45ft long by 12ft wide by 2in thick, there being 15-ton and 10-ton overhead cranes in the shop. Adequate welding facilities around the dock and at the quay and in the platers' shop for prefabrication will include automatic welding machines.

Should major engine repairs be required, it is considered that local marine engineering shops will be able to undertake them, and also major boiler repairs on any type of marine engine or boiler. The dock facilities, however, include provision for usual running repairs of marine engines, auxiliaries and boilers.

A tank cleaning and gas freeing berth is to be provided in the harbour near to the dry dock where vessels up to 100,000 tons deadweight will be able to berth. This installation is designed to deal with 1000 tons per hour of heavily contaminated ballast. There are also to be tank washing, gas freeing and sludge removal facilities, and vacuum cleaning for bunker tanks and double bottom tanks.

Repair Quay

The repair quay is designed as a reinforced concrete superstructure carried on a system of vertical and raking prestressed concrete piles with heavy steel sheet piling to retain the ground behind.

The superstructure incorporates crane beams, and a berthing wall connected with cross ribs and a slab positioned at such a depth so as to provide the maximum relieving action from earth pressure on the sheet piling. The box-like cross section of the quay will be in-filled with selected material, the whole forming a robust structure to absorb the impacts and loads from ships berthing alongside. The service subway will run the full length of the quay. Bollards and timber and rubber fenders will be fitted. Four heavy mooring points will be constructed behind the quay.

Tanker Cleaning Installation

The jetty for vessels using the tanker cleaning installation will project almost 200ft into the Great Harbour to obtain the depth of water required. The structure is to be " T "-shaped with the head extending for some 300ft, formed with three main strongpoints. These strongpoints will be constructed with a heavy concrete deck supported on a system of vertical and raking prestressed concrete piles. Gravity fenders will be installed at each strongpoint.

A combined roadway and pipe track constructed as a reinforced concrete beam and slab structure supported on piles will link the jetty to the shore-based installation. Hose handling gear will connect the ships' tanks to the main pipelines feeding the installation. The installation comprises oil separator equipment, large storage tanks, process tanks, pumps and other ancillary equipment. Some of the larger tanks will require to be supported on piled foundations and reinforced concrete walls will isolate the oil compounds.

General Yard Services

A comprehensive road system will be constructed within the dockyard area together with drainage and electrical services. An arrangement has been made whereby ships' sewage can be connected to the shore and pumped into the burgh drainage system. Floodlighting will be installed.

Firms Responsible for the Project

The principal firms involved in the design and construction of the project are as follows. The consulting engineers are Messrs. Burns-Babtie (i.e. Messrs. T. F. Burns and Partners and Messrs. Babtie, Shaw and Morton). The main civil engineering contractor is Edmund Nuttall Sons and Co. (London) Ltd. Pumping equipment will be the responsibility of Drysdale and Co. Ltd ; the dock gate, the Fairfield Shipbuilding and Engineering Company Ltd. ; piping installations for all piped services, James Mitchell and Sons (Greenock) Ltd. ; compressors, Consolidated Pneumatic Tool Company Ltd. ; and boiler installation, Penman and Co. Ltd.

SHORTER REPORTS

British Nuclear Energy Society

THE British Nuclear Energy Society will be established on January 1, 1962, to succeed the British Nuclear Energy Conference* (B.N.E.C.). In an announcement made in the October issue of the B.N.E.C. quarterly journal, the chairman of the Conference, Sir Leonard Owen wrote . "The Board of the Conference feels that the time has now come to provide a central forum for the discussion of nuclear energy and it is for this purpose that the British Nuclear Energy Society has been established. The Institution of Civil Engineers has made its premises in Westminster available as a meeting place, and a regular programme of papers, lectures, symposia and informal discussions is being planned."

The announcement stated that the Society would (as the Conference has done) publish a quarterly journal which, besides presenting a wide variety of important papers and discussions on them, would also contain information and "authoritative scientific and technological comment on the latest developments in nuclear energy throughout the world." Reports on the proceedings at meetings of the Society will also be included. The first issue of the journal is to be published in January next.

Membership of the new Society will be open, on application, to members of the constituent societies of the British Nuclear Energy Conference, and to all who satisfy the Board that they are "actively engaged in the professional, scientific, or technical aspects of the application of nuclear energy and ancillary subjects."

To ensure continuity, for the first year the affairs of the Society will be managed by the present Board of the British Nuclear Energy Conference, but thereafter the Board will include members elected by and from the general membership of the Society.

2000MW Power Station at Eggborough

THE Central Electricity Generating Board states that the Minister of Power has given his consent to the building of the second of the two large new power stations planned for the West Riding of Yorkshire. It will be recalled that consent for the first of these stations, Ferrybridge-"C," has already been given, as reported in our issue of August 18, 1961. The second station will be sited at Eggborough on the River Aire, about six miles east of Ferrybridge, and the main plant in it will consist of four 500MW turbo-generators, and four coal-fired boilers each having an evaporative capacity of nearly 3,500,000 lb of steam per hour.

Site work at Eggborough is expected to be started early next year. The first generating set is due to be commissioned in 1966 and the whole station in 1968—a year later than Ferrybridge-"C." When completed Eggborough and Ferrybridge-"C" will each burn about 5,000,000 tons of fuel a year and during their useful life will offer an assured market for Yorkshire coal.

Tracing a Leak in a Water System

AN interesting note received from the United Kingdom Atomic Energy Authority describes how a successful operation was recently carried out at the London headquarters of Firth Cleveland Ltd. to determine the position of a leak in a buried heating system from which about 5 gallons of water per hour was escaping. Since the pipe duct was full of water attempts to trace the source of the leak by audible means had provided no result. The main, 1¼in i.d., was of welded joint construction.

For the detection method adopted a piece of expanded rubber was cut into a roughly accurate spherical ball of just under 1¼in diameter and into its centre there was inserted a 25 mgm pellet of irradiated sodium bicarbonate containing 50 μc of ^{24}Na sealed in metal foil. The ball was compressed to pass down a ¾in radiator feed line into the 1¼in main, well in advance of the suspect area. All outlets to the system were then closed and the water turned on at normal pressure, but not using the circulating pump. The flow towards the leak carried the "radioactive" ball at a speed of approximately 1ft per minute inside the pipe, round corners, past radiator connections, and even through a change of level. The position of the ball was continuously monitored from floor level, through various thicknesses of concrete up to 9in, and through granolithic, cork and linoleum floor coverings, using portable ratemeters with scintillation counter detectors. The ball travelled quite steadily at the leak flow rate until it reached the first of two leaks, where it was stopped by the outwards flow of water. Subsequently the ball was persuaded to pass this point by adjustment of the water pressure and it then moved on more slowly to where a smaller bore pipe which was also leaking branched from the main. Beyond this point the ball was not carried as there was no further leak flow.

By the adoption of this non-destructive method of testing for leaks over 60ft of pipe running through occupied offices and busy corridors was confirmed as clear of leakage, without interruption to normal office working. Subsequent excavation outside office hours proved the complete accuracy of the location of the leaks by the rubber ball with its insert.

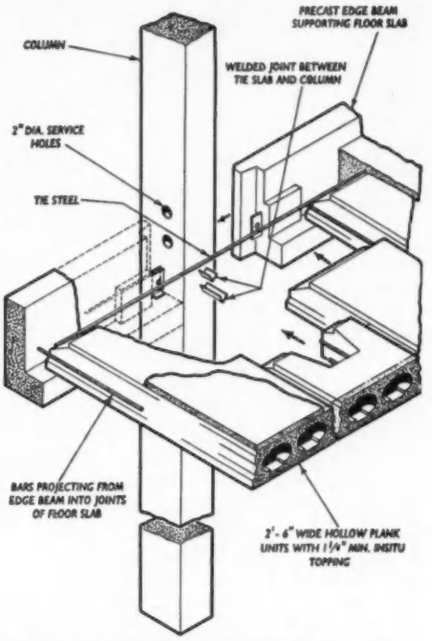
"Preferred Dimension" Building Frame in Precast Concrete

ABOUT eighteen months ago we briefly described in this journal* a precast concrete building frame which had been developed by Concrete Ltd., and of which, we stated "it is considered to be somewhere near the ultimate in simplicity, and it is probable that no further refinement is possible in the use of precast concrete for a frame of this kind." Last week Concrete Ltd. introduced its "preferred dimension" frame at a Press conference, and claimed that a reduction of about 15 per cent in the cost of a building frame had been achieved by this new development. It is of interest that, structurally, the "preferred dimension" frame is substantially the same as the frame we described last year, which might perhaps be considered as its prototype. Economy has been sought, however, in standardisation, such that while a relatively few types of standard components suffice, considerable flexibility in planning a building is possible and pretty well complete freedom in its architectural treatment results. In fact the aim of the system has been to achieve the cost reduction inherent in standardisation, without introducing any compensating disadvantages in the design of individual buildings which utilise it.

The accompanying illustration shows typical details of the "preferred dimension" frame, showing the prestressed hollow planks used for the floors with an *in situ* topping, the beams with welded steel-to-steel supports at the columns, and various other details all similar to the earlier frame referred to, except that the pitched roof has been dispensed with in the standard designs.

The columns of the "preferred dimension" frame are cast in one piece. The frame is intended for buildings such as schools and hospitals, and it may be up to four storeys in height. Columns may be spaced at 10ft, 12ft 6in, 15ft, 17ft 6in or 20ft. The height from the ground to the first floor may vary from 10ft by 1ft intervals to 15ft. Floor heights above may be 10ft, 11ft or 12ft. The transverse dimension of the frames is infinitely variable, up to a maximum span of 36ft, with some limitation below this for extra-heavy loading, and a maximum spacing of internal columns of 25ft. These are the "preferred dimensions."

It is of interest to note where the economies of the system accrue. The largest single economy is in mould costs. There is also a worth-while


PRECAST EDGE BEAM SUPPORTING FLOOR SLAB
COLUMN
WELDED JOINT BETWEEN TIE SLAB AND COLUMN
2" DIA. SERVICE HOLES
TIE STEEL
BARS PROJECTING FROM EDGE BEAM INTO JOINTS OF FLOOR SLAB
2'-6" WIDE HOLLOW PLANK UNITS WITH 1¼" MIN. INSITU TOPPING

Typical constructional detail of precast frame

economy in the drawing office, and design of frames built on this system has been reduced to reference to a set of tables. Thirdly, the production flow is simplified. And fourthly, standardisation is expected to give worth-while advantages on site, not only in the erection of the standard frame itself, where a reduction of up to a third in erection time is expected, but also in the installation of services. The construction of the frame is shown well by the typical joint illustrated. Welded steel joints, reduction to a minimum of joints, and a minimum of *in situ* concrete requiring no external strutting, are features of its design. Also the beams have an arris on each side of their soffits, so an acceptable ceiling is produced by the beams themselves.

Microwave Valves Conference

SEPTEMBER, 1963, is the date chosen for the conference on the design and use of microwave valves which is being organised by the Electronics and Communications Section of The Institution of Electrical Engineers, and will be held at the I.E.E. headquarters, Savoy Place, London, W.C.2. It is proposed to associate a scientific exhibition with the conference. The main purpose of the conference will be to review present microwave techniques and to enable potential users to learn what developments are taking place. In particular, the conference will provide an opportunity for those in the United Kingdom who are unable to attend international conventions to keep themselves fully informed. Papers are now invited from prospective authors by the organising committee which has been set up under the chairmanship of Mr. A. J. Young, and further information may be obtained from the secretary of the Institution, Savoy Place, London, W.C.2.

* The British Nuclear Energy Conference was established in 1955 by the Institution of Civil Engineers, the Institution of Mechanical Engineers, the Institution of Electrical Engineers, the Institute of Physics and the Institution of Chemical Engineers, who were joined later by the Iron and Steel Institute, the Institute of Metals, the Institute of Fuel and the Joint Panel on Nuclear Marine Propulsion.

* "Precast Concrete Manufacture at a Hounslow Works," THE ENGINEER, April 22, 1960, page 689.

SHORTER REPORTS *(Continued)*

A Revolutionary Mine-Detector Equipment

BY OUR NAVAL CORRESPONDENT

BEFORE the days of thermo-nuclear missiles, Communist aggression in Korea made it urgently necessary for Britain to start a new naval building programme to deal with two dangers of a new kind which had arisen during World War II—the fast underwater vessel, and the magnetic or other influence ground non-contact mine. Large numbers of two sizes of a new type of minesweeper—one of about 400 tons and another much smaller of about 150 tons—were built to deal with the mine danger and it is very satisfactory that 175 of these minesweeping vessels are still in service with the Royal Navy. No less satisfactory is the great progress that has been made by the Royal Navy in the detection of ground mines, for it is now universally realised that under the umbrella of the H-missile, there are as many opportunities to-day as in the past for aggression provided it is limited in aim and scale. The Royal Navy has in fact in recent years performed one more service for the N.A.T.O. navies in producing a means of quickly locating unknown positions of underwater objects, which is believed to be the most effective method of mine-hunting at present in existence. It is an all-British development of Asdic which enables a minesweeper to locate and classify any mine-like object on the seabed with an accuracy and range hitherto impossible. All that is needed is for the reported position of the object to be known very approximately—within a few miles only. The new equipment will do much to simplify the task of minesweepers, which was made so much more difficult in the Second World War by the use of the ground, or non-contact mine. Apart from the normal daily minesweeping for moored mines, channels had to be continuously swept by vessels fitted with special types of sweeps suitable for blowing up magnetic and acoustic mines at a safe distance from the minesweepers. Moreover these sweeps were often ineffective because of the delayed action operation of the mine. The ground mine is the simplest of all mines to lay, as it has negative buoyancy, and thus acts as its own sinker. Hence it is eminently suitable for laying from aircraft or from the torpedo tube of a submarine, and cannot be located and destroyed by the sweep-wires of the normal minesweeping vessel. But with this new mine-hunting device channels can be searched with safety and thoroughly by a single minesweeper and the local authorities informed at once if a ground mine has been located.

One of the 175 post-war minesweeping vessels—the 400-ton H.M.S. "Shoulton," which paid a brief visit to Greenwich earlier this month—after being fitted with the new equipment demonstrated it to the Americans in 1960 when carrying out side-by-side trials with United States Navy minesweepers. It was immediately regarded by them as a significant contribution to the art and science of mine-hunting, and a similar type of equipment is now in use in the United States Navy, together with the other all-British innovations it has adopted—the angled deck and steam catapult—which have made it possible to operate modern heavy fast aircraft from an aircraft carrier. During the past twelve months H.M.S. "Shoulton" has also demonstrated the equipment to the navies of fourteen N.A.T.O. and S.E.A.T.O. countries and over 250 officers from those navies have had the privilege of seeing the system at work in the specially designed, air-conditioned operations room, manned by two officers and three ratings. In spite of so many foreign officers having witnessed the system in operation, it is still thought possible to keep secret its range, degree of accuracy and other performance details which remain classified. Though designed for locating mines, the equipment has already proved invaluable both in this country and abroad in finding crashed aircraft, rockets and other weapons at sea. The ships' company of five officers and thirty-one ratings includes a team of divers who have sometimes operated in water temperatures down to 4 deg. Cent. to confirm contacts obtained by the mine-hunting system. The complement are trained as a team to operate the ship as a mine-hunter and in the first half of this year spent 118 days at sea and took part in four naval exercises. Over 400 hours of operational experience has been gained with the Asdic system since the end of last year and during the two-and-a-half years in which the system has been operated in H.M.S. "Shoulton" she has been called on by several countries to search for a variety of underwater objects. On her last aircraft search she succeeded in finding a crashed helicopter after only four minutes' operation. It is intended that other coastal minesweepers will, in the future, be fitted with the equipment and converted for a mine-hunting role. The "Shoulton" class are powered by high-speed lightweight diesels driving two propellers, and fitted with active rudders for ease of manoeuvring at slow speed. Their hulls are built of two thicknesses of mahogany, and metal fittings are mainly of aluminium alloy to make them as safe as possible against magnetic mines. All underwater surfaces of the wooden hull are covered with fibreglass as a protection against marine boring worms.

Control Systems Analyser

SEQUENTIAL testing of electronic and other control systems, with fault location and diagnosis, are provided by a systems analyser demonstrated in London last week by Honeywell Controls Ltd., Greenford, Middx. It was announced on this occasion that orders for a number of the analysers have been placed by the R.A.F. for use with English Electric "Lightning" aircraft. The analyser operates to a tape-controlled programme which initiates the tests and provides the references against which the results are compared, this comparison forming the basis for deciding the nature of the fault. Two digital indicators show the test in progress and its sub-routine. If apparatus is faulty a "malfunction" light appears on the control panel seen in the illustration, and a roller chart is manipulated until the test and sub-routine numbers being displayed by the digital indicators appear in an aperture on the panel. The fault and its probable cause are then read off the chart. For operational use, the fault is generally identified as being in a particular control system element which can be removed and replaced as a unit. Programming is arranged so that tests cover the overall performance of interdependent circuits. While primarily concerned with electronic testing in its present form, the analyser can cover pneumatic, hydraulic and lubrication systems through the intermediary of suitable transducers. An air data computer could be tested by simulating inputs.

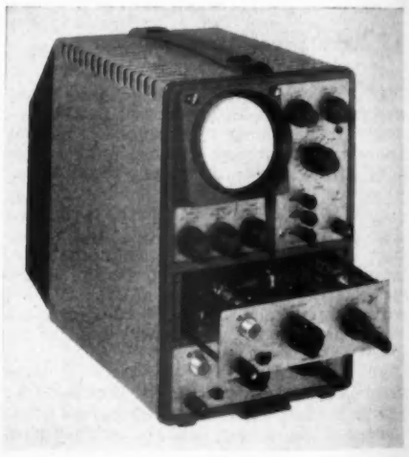
Aircraft electronics test gear, showing arrangement of modules on withdrawal trays

Analysers are built to suit the systems test requirements of individual aircraft. Modular construction is employed, the basic analyser consisting of 100 modules mounted in drawers as illustrated. Test routines, including self-checking functions, are worked through at a rate enabling a complete programme on a fighter aircraft to be completed in two hours thirty minutes, and improvements on present figures are expected. By splitting test programmes between a number of tapes, time is saved in carrying out a test on a particular part of the aircraft system which has been reported faulty by a pilot. With further miniaturisation of components, the possibility will arise of building-in continuous self-monitoring techniques.

[Reply Card No. 1306]

Adaptable Oscilloscope System

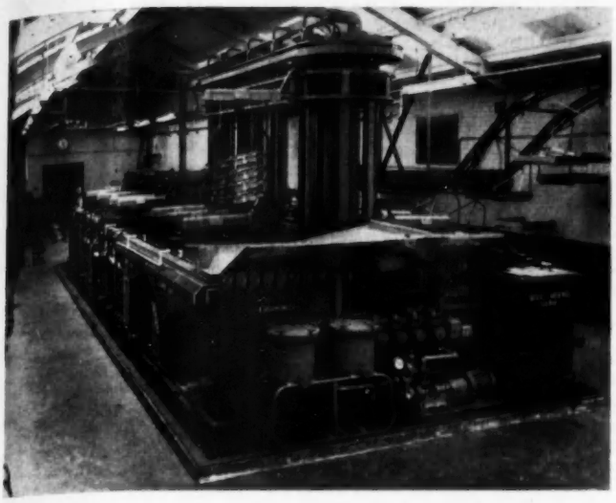
WE illustrate the D33 oscilloscope introduced by Telequipment Ltd., 313, Chase Road, London, N.14, in which adaptability to a wide range of applications is obtained by means of interchangeable amplifiers which slide into the front of the instrument as shown. The basic range consists of a general-purpose amplifier with the facility of additional sensitivity over a limited bandwidth; a high-gain differential amplifier which can be used for working with the oscilloscope in the electro-mechanical, medical and biological fields; and an ultra-high-gain amplifier intended principally for electro-acoustical and magnetic recording applications. Other amplifiers can be built to special requirements. The post-deflection acceleration tube operates at 3500V. Accessories include a high-impedance divider probe, camera attachment, and extensible light hood.



Oscilloscope with interchangeable amplifiers

A similar p.d.a tube is used in the Model S32 oscilloscope announced by the same firm, which is a compact design weighing only 16 lb but capable of fast pulse rates suitable for electro-medical, medical and biological work in addition to numerous general electronic, radio and television applications.

[Reply Card No. 1310]



Rim plating plant. A jig of rims can be seen in course of transfer from one of the plating cells to the rinse tank

Automatic Wheel Rim Plating Plant

A PLATING plant has recently been installed at the Coventry works of Triumph Engineering Ltd. by W. Canning and Co. Ltd., Great Hampton Street, Birmingham, 18, for the nickel and chromium plating of motor-cycle wheel rims, and other components. The plant employs the multiple cell plating principle whereby the work, instead of progressing through the bright nickel tank is set down in one of eight different sections or cells, with the rims held horizontally in the jig and surrounding a fixed central core of nickel anodes. With this arrangement, since the work is stationary, it is possible for the anodes to be positioned so that the most efficient current distribution is obtained. It is stated that the introduction of this automatic plant has enabled the users to increase considerably the output of plated motor-cycle rims and at the same time ensure a standard of finish to a degree of uniformity not previously achieved, indeed on a production of 40,000 rims the rejects were less than 0·1 per cent.

The automatic plating plant, illustrated above, supersedes manually operated equipment, and is housed in a new two-storey building. In this building the rectifiers, pumps, compressed air equipment and other ancillary plant have been installed on the ground floor whilst the plating plant itself is on the floor above.

The plating plant, with a length of 47ft and a width of 13ft, is arranged in two sections. The first section, comprising the cleaning and chrome plating tanks and swills, is of a standard Canning design whilst the other section is made up of the specially designed nickel plating tanks. Each work arm is transferred between the first and second sections by a solenoid-operated pick-up pawl and the arms are carried to vacant nickels stations by pushers fitted to an overhead transfer chain. An indexing switch which determines the loading sequence of the nickel stations, energises a solenoid-operated lifting and lowering pawl when an arm reaches an empty station.

The plant has an output of forty-eight rims per hour, and loading and unloading of the plating jigs is accomplished by one operator. The work arms are fitted with additional hooks so that standard plating jigs may be used in place of those for rims.

Instrument Works Extension

AN instrument assembly wing providing some 15,000 square feet of working area has been added to the premises of the Cambridge Instrument Company Ltd. in Chesterton Road, Cambridge. As seen in one of the accompanying illustrations, the new wing blends with the entrance hall and research laboratory block opened in 1959, and consists of two raised storeys with a ground level car park beneath. Structurally, the two upper storeys consist of a box, with a reinforced concrete frame, approximately 150ft long and 50ft in depth, based on on a solid concrete slab supported by two rows or circular columns from which the slab cantilevers out about 8ft front and back. Accommodation on the first floor is divided between offices and the microanalyser department. The whole of the second floor is used for instrument assembly and testing. The building was designed by Edward D. Mills and Partners, architects, and was completed in less than a year by J. Jarvis and Sons Ltd., general contractors.

The new wing was opened on October 23 by Sir Keith Joseph, Bt., M.P., Minister of State, Board of Trade. At a luncheon after the ceremony Dr. P. Dunsheath, chairman of the company, referred to the success of the Cambridge "Microscan" X-ray analyser for metallurgical research, which he described as an advance likely to have an impact comparable with that of the electron microscope. Eight of these instruments, he said, had now been sold to the United States, and four to Europe. The company's export business had increased from £360,000 to £525,000 (46 per cent) between 1959 and 1960, and this year should exceed £600,000 in value. In conclusion Dr. Dunsheath announced an agreement which had just been concluded between the Cambridge Instrument Company Ltd. and Instrumenti di Misura C.G.S. of Monza (Milan, Italy) for the formation of a new joint company, Cambridge–C.G.S., which will have its factory at Casoria, near Naples. Cambridge–C.G.S. will initially manufacture instruments based on Cambridge designs, including electronic and galvanometric indicators and recorders for a wide range of applications, and associated control equipment. These will, where necessary, be adapted to meet the requirements of the Italian and neighbouring markets. Distribution will be in the hands of C.G.S. and Soc. Ing. Taragni, the latter having for many years acted as agent in Italy for the Cambridge Instrument Company Ltd.

After the luncheon, guests inspected the new wing and various exhibits representing production and development work at Cambridge. Demonstrations were given of the "Microscan" analyser (THE ENGINEER, October 23, 1959, page 484) and work was seen in connection with adapting the instrument for slow scan rates, down to 1 micron per minute. The unit developer for this purpose could be used either to generate an ultra-slow single line scan, or to produce a slow raster in conjunction with the existing "Microscan" line timebase circuit. Improvements in the "Microscan" power supplied are also in hand; measurements are being made of an 80 kc/s ripple which occurs in the oscillator-derived e.h.t. supply with a view to its elimination, and studies are taking place of noise in the neon voltage stabiliser system.

A prototype data recorder was shown for recording slowly-varying phenomena on tape and reproducing them, suitably accelerated, so as to appear as a complete waveform on an oscilloscope. Improvements in Cambridge katharometers, which are the primary measuring elements in the company's thermal conductivity gas analysers, are concerned with welding connecting wires to the filaments. Spot welds are being made under automatic time control by a condenser discharge circuit, and important reductions of resistance have resulted from the uniformity of the welds. Pilot production has begun of moving coil galvanometer movements having taut wire suspension in which the coil is superseded by metal bands providing control force, and electrical connections are replacing wearing parts such as pivots, jewels, hairsprings and current spirals.

Two-floor assembly wing extension at instrument works

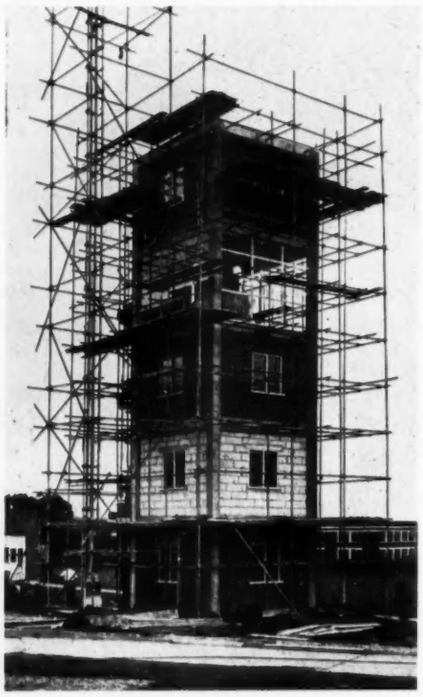
Part of the microanalyser department on the first floor of the new wing

SHORTER REPORTS *(Continued)*

Research on Off-Peak Electricity Consumption for Space Heating

A SPECIAL five-storey building is being erected at the Leatherhead laboratories of the Electrical Research Association (E.R.A.) to enable highly refined methods to be applied to the study of the effects of weather on electricity consumption for space heating.

Considerable research has already been done on off-peak floor heating by electricity. For example, because the performance of such a heating system depends on the nature of the structure, including the walls of a building, the E.R.A. has erected several experimental buildings in the laboratory grounds at Leatherhead. Three



Five-storey building at E.R.A. laboratories, Leatherhead, for research into effects of weather on consumption of off-peak electricity for space heating

of them have been in use for about two years and consist of an instrument cubicle and two single-storey huts which can be arranged to simulate the corners either of a large heavy-walled office building or of a large light-walled factory building. They are used for making simple comparisons of the amount of electricity needed, say, for direct electrical heating in the daytime and for off-peak floor heating, to produce the same daytime temperature in each case. Weather changes are observed and noted but the present controls are simple thermostats and the information derived from an experiment is merely the total quantity of electricity consumed during the whole heating season.

At the same time other experiments on electrical heating have been carried out with the co-operation of a number of typical householders, but imponderable factors such as the conditions of occupancy of the houses have made it impossible to correlate variations in weather conditions with the consumption of electricity for space heating.

Now it is proposed to carry the work to a more advanced stage by attempting to establish reasonably accurate relationships between this electricity consumption and weather conditions such as solar gain, wind speed and cloud cover. The ultimate object of the work is to accumulate sufficient data to yield a formula whereby the hours of overnight heating can be calculated if the weather forecast is known. Thus, if anticipatory control of off-peak heating systems becomes practicable, substantial economies in the consumption of electricity should accrue.

The new five-storey building, illustrated here, is specially designed for this work. It will be possible to maintain constant temperatures inside the building and to find the effect of weather changes on the quantity of electricity needed to preheat a floor for daytime comfort. Each storey consists of a single rectangular room with a square floor 12ft by 12ft but the rooms have different wall structures. The top, central and ground-floor rooms have 11in cavity brick walls. The first-floor room has walls of special lightweight concrete, with good thermal insulation. The third-floor room has 32-oz glass-curtain walls. To simulate the effect of an inside wall in an ordinary building, the north wall on each floor will be of cavity brick (containing all the pipework and services) and will be covered internally with a thick layer of insulation to make the heat loss through it negligible.

This work, which has the special support of the Electricity Council, will involve the continuous recording of weather conditions and short period observations of electricity consumption, and the information obtained will be analysed statistically. The first part of the experimental programme will be concerned with separating the various effects of the weather. These tests will reveal the variations in the number of units required to keep a constant night-and-day temperature in each room. Changes in the time lag will be logged and correlated with the causal weather conditions. Having isolated and studied these effects, which will probably take two winters, the next steps will be to use off-peak or intermittent heating to simulate occupancy of the rooms and, generally, to introduce deliberate disturbances, so that their influence can be assessed.

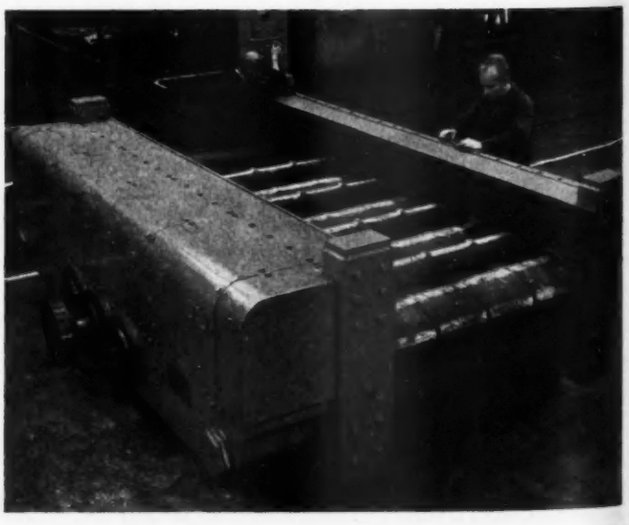
Grizzly Feeders

A RANGE of "Jar-bar" grizzly feeders in production at the Fraser and Chalmers Engineering Works of The General Electric Company Ltd., are the first of their type to be manufactured in this country and are stated to be particularly suitable for removing clay or sticky fines from ore or stone before it enters a primary crushing plant. Two types of machines are available, one for standard duty and the other for heavy duty, and both can be fitted with eight, ten, twelve or fourteen rolls. The heavy-duty machines are made with widths of 48in, 60in, or 72in and have capacities up to 5000 tons per hour. The standard-duty machines are available with widths of 24in, 30in, 36in, or 48in and have capacities up to 2000 tons per hour. This design of grizzly feeder employs elliptically-shaped rolls and, since the rolls are arranged with the major axes of adjacent bars at right angles, forward feed can be obtained with the machine mounted horizontally or inclined upwards. The feeder can be arranged to spread the fines load evenly over the conveyor belt by varying the discharge setting for each pair of rolls, so that a graduated discharge size (such as from 1½in up to 10in) may be obtained on one machine. The elliptical rolls rotate in the same direction with the major axes of adjacent rolls at right-angles and the rolls are so shaped that the aperture between adjacent members remains constant throughout the whole circle of rotation. A typical 48in wide, eight-roll machine can be seen in its final assembly stage at the makers works in our illustration below.

Each side of the welded frame consists of two beams with the housings of the bearings for the bars secured between them. Removable spacing pieces between the bearing housings locate the bars in their correct positions and provide means for the adjustment of the discharge size. The cast elliptical bars have ribs spaced at intervals along their length and projecting from both ends are stub shafts for supporting them in their bearings. In the standard model the major axis of each bar is 10½in long and the ribs are spaced 6in apart; in the heavy-duty model each of these dimensions is 12in. Each of the rolls is a single unit complete with its bearings and can be readily removed if required. The bars are rotated by a heavy-duty triplex chain running over sprockets mounted on the stub shafts of the rolls at one side of the frame. Chain tensioning facilities are provided, and the whole chain-drive assembly is enclosed in a casing, the base of which forms the oil bath for lubrication.

In operation the lumps of rock which are in contact with the rolls are alternately lifted and dropped and at the same time they are moved forward as the elliptical sections rise and turn over. This movement occurs twice per revolution. As the major axes are at right-angles, the pieces of rock over adjacent rolls are moving in opposite directions, one rising while the other is falling. This relative movement results in a rocking motion with a rubbing as well as a sifting action, which has the effect of not only shaking the fines rapidly downwards, but also of breaking up any large lumps of clay and working them downwards as well. On reaching the bars the fines pass through freely and although the clay tends to stick it is forced down between the bars by the weight of the rock continually dropping on top of it. The whole material mass is in a state of mobility that induces a rapid forward travel without any tendency to pack or bridge in the feeder.

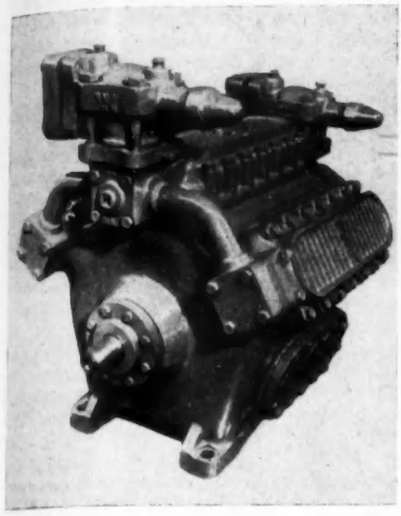
[Reply Card No. 1313]



48in wide, eight-roll grizzly feeder from the drive side

Refrigerant Compressors

We illustrate a typical model from a range of compressors now made by York Shipley Ltd., North Circular Road, London, N.W.2, for use with refrigerants 12 and 22. These compressors are available as three-, six- and nine-cylinder machines to meet refrigeration requirements



Compressor with automatic cylinder loading and unloading for refrigerants 12 and 22

from 5 to 60 tons, and they incorporate means of individual cylinder unloading to give wide flexibility in operation. The loading and unloading of the cylinders is effected automatically by an internal capacity valve.

Machines can be supplied for vee-belt or direct drive in a speed range from 900 to 1750 r.p.m., and their static and dynamic balancing with the V or W cylinder arrangement allows floor mounting without need for special foundations. The use of a large suction chamber reduces pulsation, and large non-rotating ring plate valves are designed to reduce chatter to a minimum. A gear pump which delivers lubricating oil to the bearings also supplies oil to the capacity control system of the compressors.

[Reply Card No. 1272]

Lightweight Portable Conveyor

A GENERAL purpose portable conveyor designed for such work as lorry loading, materials stacking and horizontal conveying, introduced by Gardiner's Conveyors Ltd., 10–16, Lafone Street, London, S.E.1, is available with 9ft or 12ft booms giving respective delivery heights up to 6ft and 8ft 6in. One of these "Conveyorettes" is illustrated here. They have a main boom which is constructed in 14 gauge aluminium and carries a grip-face three-ply belt 14in wide. Two 5in diameter retractable rubber-tyred wheels facilitate movement of a conveyor between working sites, and a locking device ensures a firm stand when a machine is in use.

General purpose portable conveyor available with boom lengths of 9ft and 12ft and having a belt speed of about 60ft per minute

The belt is driven by a ¾ h.p. three-phase electric motor, the motor, drive, switchgear and return band being totally enclosed by panelling but easily accessible for maintenance purposes. In operation, the outer end of the boom needs to be lightly supported. A simple rotary switch gives forward, stop and reverse control of the belt, the speed of which is approximately 60ft per minute, depending on the load. The recommended maximum distributed load when operating is 1 cwt for each model of the conveyors, which have net weights of 2½ cwt in the case of the 9ft boom model and 2¾ cwt for the 12ft model.

[Reply Card No. 1254]

Perforated Metals

PERFORATED metal made by N. Greening and Sons Ltd., of Warrington, known as "Perflec," is made in a wide range with hole sizes from 0·027in down to 0·003in and in special grades with holes as small as 0·001in. The material consists of a copper core heavily clad with pure nickel and is available in normal thicknesses (depending on the mesh count) between 0·010in and 0·003in. It is flat, smooth and tough, and can be easily cut, punched, or formed whilst, as it cannot fray, edge binding is normally unnecessary. The maker states that the rigid integral construction gives freedom from aperture distortion under stress and permits formed cylinders to be used unsupported.

The material is characterised by its regularity of pitch and aperture size, and the slight taper of the square apertures make it very suitable for filters which are "back washed" for cleaning. Standard "Perflec" is made in rolls 3ft wide and up to 100ft long and it is available in five counts producing fifteen aperture sizes and thicknesses.

[Reply Card No. 1185]

Bench Power Supply

DECADE switches provide voltage selection in the AS 1165 general-purpose bench-mounting power supply unit for thermionic valve circuits which has been introduced by Solartron Laboratory Instruments Ltd., Cox Lane, Chessington, Surrey. The unit, which we illustrate, provides two individually stabilised and electrically isolated h.t. supplies (OP1 and OP2) which may be used independently or in series. A low-current output (OP3) is derived from OP2 by means of a cathode follower. Three decade switches enable OP1 voltage to be set in 1V increments to any value between 0 and 500V. This supply has a maximum current rating of 350mA, and a regulation of 0·025 per cent. Output OP2 provides a fixed potential of between 200V and 250V, as preselected by an internal control. The maximum available output current is dependent upon the delivered voltage and varies linearly from 100mA at 250V to 75mA at 200V, with a regulation of 0·01 per cent. The output voltage obtainable from OP3 can be varied continuously between OP1 and (OP2—10V) with a maximum load current of ±3mA. Ripple and noise component on all three supplies is approximately 1mV peak-to-peak.

Laboratory power unit for thermionic valve circuits. Output voltage is controlled by decade switches

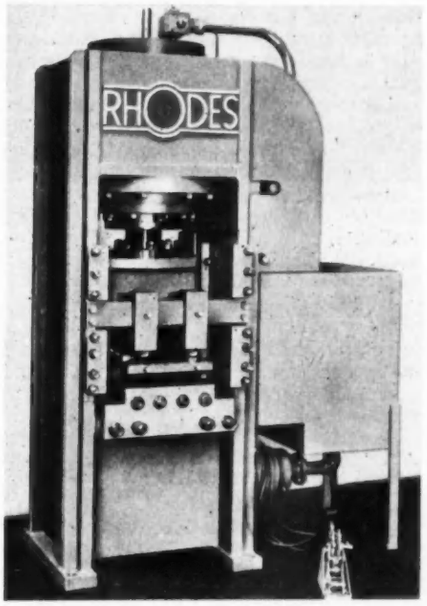
An overload cut-out, tripping at a nominal current of 420mA, is provided on the OP1 output, visual warning of operation being given by a panel-mounted indicator lamp. The OP1 and OP2+OP3 supplies are independently switched, and the load currents monitored on a dual-range meter. Two independent a.c. heater voltages of 6·3V at 5A each are provided, and may be operated in series or in parallel. The insulation between supplies and from each supply to chassis is tested to 2000V. The unit will operate from 100–125V/200–250V, 50–60 c/s, a.c. mains input and has a power consumption of approximately 575VA at maximum output. Measurements of the instrument are 18½in wide by 9¾in high by 16½in deep. The weight is 55 lb.

[Reply Card No. 1273]

Billet Shear

A BILLET shear with a stroke of 5in and a working pressure of 150 tons which has been introduced by Joseph Rhodes and Sons Ltd., Wakefield, is designed to take 12in by 1in steel and operate with single or continuous stoking. This machine is actuated electro-hydraulically, and its mechanism is fully protected from damage by overloading by a pressure relief valve in the pneumatically controlled hydraulic circuit.

The shears, illustrated below, are of welded steel plate construction, and long slideways ensure precise alignment of the ram to impart a long effective blade life. Renewable blades with jaw cutting edges are used on the machine. Although this machine is primarily designed as a billet shear it can easily be arranged to provide a hydraulic double-sided press.



5in stroke billet shear for mild or stainless steel up to 12in by 1in

[Reply Card No. 1307]

Launches and Trial Trips

CLAN FRASER, cargo ship; built at Wallsend by Swan, Hunter and Wigham Richardson Ltd., for Clan Line Steamers Ltd.; length between perpendiculars 460ft, breadth moulded 62ft 3in, depth moulded to upper deck 37ft 6in; gross tonnage 9242, bale capacity 584,430 cubic feet, service speed 16 knots; five main cargo holds, one 80-ton, two 20-ton, two 15-ton, two 10-ton and ten 5-ton derricks, electric winches, three 185kW diesel-driven generators; Wallsend-Sulzer, single-acting, supercharged oil engine, six cylinders 760mm bore by 1550mm stroke, 710 b.h.p. at 112 r.p.m. Launch, July 27.

INDUSTRIAL NEWS

Overseas Trade

The final figures issued by the Board of Trade for United Kingdom trade in September show that exports were valued at £206,500,000, imports at £343,100,000, and re-exports at £12,500,000. Exports in the third quarter of 1961 were 1 per cent more than in the second quarter, and at the same level as in the first quarter of the year.

Exports of engineering products showed a rise, seasonally adjusted, in the third quarter of £14,000,000 or 3 per cent. Most of the increase, the Board states, was in machinery and instruments, but there were also increases in exports of ships and road vehicles. Compared with a year earlier, exports of machinery and instruments were 17 per cent greater. There were more than average increases in exports of boilers and boiler-house plant which, not including steam engines, were 59 per cent higher than a year earlier, aircraft engines were 29 per cent higher, internal combustion engines 18 per cent, machine tools 35 per cent, excavating and earthmoving machinery 45 per cent, and textile machinery 28 per cent. All of these items, the Board says, except textile machinery, had shown smaller increases on a year earlier in the second quarter. Exports of agricultural machinery were greater by 12 per cent, but had been 20 per cent greater in the second quarter, and exports of office machinery and mechanical handling equipment, not including industrial and works trucks and tractors, were down by 3 per cent and 10 per cent. Exports of electrical machinery and apparatus were 14 per cent more than a year earlier and exports of scientific instruments 23 per cent more.

Although there was some improvement, possibly due to cars, in exports of road vehicles in the third quarter compared with the second, the Board says, exports of cars were still down by 25 per cent on the corresponding quarter of last year. Compared with the third quarter of 1959, they were down by one-third.

The Guillebaud Principle

One good result which may come out of the " pay pause," the British Employers' Confederation suggests in the current issue of its *Bulletin*, is the abandonment of the idea that wages in the nationalised industries can be determined on the basis of comparability. What has become known as the Guillebaud principle, it says, is the idea that a major factor in the determination of rates in one industry should be a comparison with rates for comparable jobs in others. Should the pay of a porter at a wayside railway station be comparable with that of an agricultural worker, the *Bulletin* asks, or the pay of a ticket collector with that of a process worker in, say, the chemical industry? Comparisons of this kind tend to be odious in an era of full employment, particularly if they are applied to a service industry where wage increases are passed straight on to the consumer and result in higher fares and freight charges.

The yardstick of capacity to pay as a major factor in collective bargaining is more difficult of application in a nationalised industry than in the private sector, the Confederation goes on to say, and this is particularly so on the railways where the provision of certain transport services may be a national but not an economic necessity. Nevertheless, there is no doubt that the railways, in common with other employers, could work on a smaller and more efficient labour force and by doing so could provide resources from which increases in railway pay could come. The *Bulletin* draws attention to a recent statement by the British Transport Commission which, it says, indicates that Dr. Beeching has this point in mind. It also quotes a spokesman for the Commission who, in replying recently to the trade unions' claim, is reported as having said, " the Commission did not agree that railway pay, irrespective of other considerations, should move automatically with pay increases elsewhere."

Effects of the " July Budget "

The current issue of the Treasury's *Bulletin for Industry* reviews the state of the United Kingdom's economy following the action taken by the Chancellor in July to check the rapidly rising home demand and to provide for a major re-deployment of resources from the home market into the export trade. The measures have already had an effect on short-term movements, the *Bulletin* says, but it is too early to assess to what extent they are making an impact on the underlying imbalance of payments.

The intention of firms in private industry and trade was that they expected to spend about 12 per cent more this year than last and a further 3 per cent next year. Within this total the investment in manufacturing industry appeared likely to reach a peak in the second half of this year, the *Bulletin* says, with some fall thereafter. There would, however, have to be a large immediate revision of plans for private investment as a whole to show much change next year, it adds, and in any case the increase in public investment implied by present programmes should ensure that fixed investment as a whole continues to rise.

The *Bulletin* goes on to suggest that the outlook for export demand, in the period ahead could be very good if openings now developing in world markets are exploited. World economic conditions have improved since the beginning of the year, it states, and for some time ahead world trade and production should be rising.

P.O. Engineers Pay Increases

The Civil Service Arbitration Tribunal has awarded pay increases ranging from £43 to £64 a year for salaried grades, and from 11s. 6d. to 17s. 6d. weekly for others, to some 75,000 members of the Post Office Engineering Union. The Tribunal has also back-dated the award to January 1, 1961. Before the two-day hearing last month the Post Office had declared that it would not pay anything in excess of its offer of 5½ per cent, and that any additional amount which might be awarded by the Tribunal would be frozen for an indefinite period and then paid without retrospection. The amount now awarded, however, represents a 7½ per cent increase for engineering grades and 6½ per cent for labourers and some ancillary grades.

At a meeting last Friday between Mr. Bevins, the Postmaster-General, and Union representatives led by Mr. Charles Smith, general secretary of the Union, Mr. Smith urged that the award should be honoured immediately and in full, and stressed that the Post Office was breaking a long-standing agreement, part of the Civil Service negotiating machinery, by refusing to honour the Tribunal's award. But Mr. Bevins refused to reconsider the decision.

After the interview Mr. Smith said that the Union thought it was deplorable that the Government should depart in this way from an arbitration award. The Government and the Press, he said, strongly condemned trade unionists who broke agreements, but here the Government was acting in disregard of an award given unanimously by an Arbitration Tribunal of three men of great experience and standing in industrial matters. The effect would be, he added, to clip sums of between 2s. and 7s. a week for an indefinite period off the amount awarded. This would total in a full year about £1,259,000. The Post Office had signed the terms of reference, which covered the question of the operative date, Mr. Smith said, and in all the long exchanges on the claim before the Chancellor's " pay pause " statement, had never questioned the view that any rates finally settled should date from January 1, 1961. The ill-feeling already caused by the reluctance of the Post Office to negotiate at all on the claim, which was tabled as long ago as last November, would be increased, he added, by its refusal to honour the award.

Miners' Wages

The National Union of Mineworkers decided at a meeting held last week to present a claim for an increase of £1 a week for 350,000 day-wage men in the collieries, including craftsmen and winding enginemen, and to submit a similar claim for some 40,000 other workers, including clerical staff. The claims will be presented to the National Coal Board at a meeting to be held on November 15. It is estimated that, if granted, these two claims would cost the Board over £20,000,000 a year. The Union's national executive is, at the same time, to demand that the adult rate should be paid to miners of eighteen years and over instead of twenty-one years and over as at present. This would affect some 26,000 workers.

Railway Wages and Hours

At a meeting of the Railway Shopmen's National Council held in London last week representatives of the employees submitted an application for a substantial increase in the rates of pay of railway workshop staff. Representatives of the British Transport Commission undertook to examine the submissions of the employees' side and to give an early reply to the claim.

Earlier this year at a meeting of the Railway Shopmen's National Council, the Commission had offered that, provided satisfactory arrangements could be agreed as to how a shorter working week could be implemented in an efficient and economic way for workshop staff, it would be prepared to consider favourably a reduction in the standard working week for railway shopmen from forty-four to forty-two hours. Last week's meeting ratified an agreement for a reduction of the shopmen's working week to be introduced as from October 30.

PERSONAL AND BUSINESS

Appointments

MR. D. D. MCGUFFIE has been elected a director of Alexander Stephen and Sons Ltd.

MR. KENNETH BROCKHOUSE HOGG has been appointed general works manager of Electronic Instruments Ltd.

MR. J. D. DUNLOP has been appointed managing director of the Tube Investments subsidiary, New Conveyor Company Ltd.

MR. R. E. FISCHBACHER, A.M.I.E.E., has been appointed an assistant director of the British Scientific Instrument Research Association.

MR. A. J. WAKELING has recently been appointed chief designer of the power transformer department of The British Electric Transformer Company Ltd.

MR. D. T. HOLLINGSWORTH, an executive director of British Insulated Callender's Cables Ltd., has been appointed a director of Submarines Cables Ltd.

MR. J. C. GLADMAN has been appointed manager of the computer engineering department, Associated Electrical Industries Ltd., electronic apparatus division, Trafford Park.

BROWN AND TAWSE PLANT LTD. announces that Mr. J. B. Fosbrooke has been appointed crane sales manager for England and Wales, and Mr. B. A. Mackie has joined the company as Hydrocon crane salesman in the Midlands area.

MR. J. A. W. GILL has been appointed a director of Baker Perkins Granbull Ltd. Mr. Gill, who is also a director of Steele and Cowlishaw Ltd., remains manager of the chemical machinery sales department of the parent company, Baker Perkins Ltd.

THE BRITISH ENGINEERS' ASSOCIATION states that Mr. E. N. Griffith, C.I.B.A.E., chairman of Rotary Hoes Ltd., has been elected president for the ensuing year. Mr. K. M. Leach, A.M.I.Mech.E., director of Serck Ltd., and of Audco Ltd., has been elected vice-president.

THE INDUSTRIAL WELFARE SOCIETY has announced the appointment of Mr. John Garnett as the Society's third director in its forty-three years' existence. The vacancy arose earlier this year when Mr. John Marsh accepted an invitation to become director of the British Institute of Management.

THE MARSHALL REFRACTORIES GROUP OF COMPANIES announces that Mr. J. R. Gledhill and Mr. A. H. Thompson, M.I.Ceram., have been appointed to the board of Thomas Marshall and Co. (Loxley) Ltd. Mr. D. Gregory has been appointed managing director of Ffrith Fireclay Company Ltd.

THE COUNCILS OF THE UNIVERSITY OF MANCHESTER and the MANCHESTER COLLEGE OF SCIENCE AND TECHNOLOGY have approved the appointment of Dr. Colin Adamson, A.M.I.E.E., to a newly-created (second) Chair in Electrical Engineering in the Faculty of Technology.

THE COUNCILS have also approved the appointment of Mr. John Robert Dark Francis, A.M.I.C.E., to be Professor of Municipal Engineering in the Faculty of Technology in succession to Professor R. J. Cornish, who recently accepted a similar appointment in the University of Delhi, India. He will take up his post in January, 1962.

LORD DUDLEY G. GORDON, M.I.Mech.E., has resigned as chairman of Hadfields Ltd., and Sir Peter G. Roberts, Bt., has been elected chairman of the company. Lord Dudley Gordon has agreed to remain on the board as an ordinary director until the annual general meeting of the company which is expected to be during February, after which it is Lord Dudley Gordon's intention to retire as he approaches his eightieth year.

GEORGE SALTER AND CO. LTD., West Bromwich, has appointed Mr. G. P. Bache a new director to take charge of the company's manufacturing interests overseas. Mr. G. P. Bache recently returned to this country from Australia where he was, for nine years, managing director of the Salter spring balance and spring factories. In his new position he will be responsible for overseas developments, and for the initiation of market analysis and other investigations.

THE BRITISH IRON AND STEEL FEDERATION announces the following appointments : Mr. E. W. Senior to be director of the Federation ; Mr. J. B. Cowper to be managing director of British Iron and Steel Corporation Ltd., in addition to his present post of financial director of the Federation ; Mr. J. Driscoll to be assistant director (economics) ; Mr. L. J. Gollop to be assistant director (statistics) ; Mr. B. S. Keeling to be assistant director (training) ; Mr. A. H. Mortimer to be assistant director (commercial), and Mr. K. Donohue to be secretary of the Federation.

Business Announcements

UNIVERSAL METALLIC PACKING COMPANY LTD. has opened London offices at 168, St. Stephen's House, Westminster, S.W.1, where Mr. E. Etherington is in control.

CLIFFORD ALLIN (ENGINEERING) LTD., Frome Top, Minchinhampton, Stroud, Glos., has been appointed sole agent by Joseph Rhodes and Sons Ltd., Wakefield, for Devon, Cornwall, Somerset, Dorset, Glos. and Herefordshire.

SOAG MACHINE TOOLS LTD., Juxon Street, London, S.E.11 is to hold a private exhibition of new machines for toolroom and production use at its London (Battersea) showrooms from Wednesday, November 15 until Friday, November 24 between 9 a.m. and 6 p.m.

W. CANNING AND CO. LTD., has opened a new Scottish branch at 33, Squire Street, Whiteinch, Glasgow, which will stock a wide range of electroplating chemicals and metals, polishing materials, brushes and lacquers. Mr. K. J. Chambers, the resident representative, has been appointed the firm's area superintendent for Scotland, and the warehouse is being managed by Mr. S. V. White who has been transferred from the Sheffield Branch.

THE BRITISH OXYGEN COMPANY LTD. has agreed with the Board of Trade to lease a site near Dumbarton on which to establish progressively a new light engineering factory, while leaving the oxygen plant manufacturing at the existing Edmonton Works. It it estimated that over two years will elapse before the first stage of the new factory is established. Thereafter, there will be a gradual build-up to a total strength of about 2000 during the following three to four years.

INTERNATIONAL MACGREGOR ORGANISATION announces the acquisition of MacGregor and Co. (Naval Architects) Ltd., of Whitley Bay, Northumberland' by Indpart (London) Ltd. In consequence of this new set-up, Mr. H. Kummerman is now managing director of MacGregor and Co. (Naval Architects) Ltd., whilst Mr. Joseph MacGregor remains as chairman. It is also announced that Mr. Raymond Nagel has been appointed assistant managing director of MacGregor and Co. (Naval Architects) Ltd., to carry out certain re-organisation. Mr. H. Danskin, Mr. J. Johnston and Mr. J. Wood remain directors ; Mr. G. Dodds, Mr. P. Durand and Mr. A. F. Sharman have been appointed to the board.

GUEST, KEEN AND NETTLEFOLDS LTD., announces that it has entered into an agreement to acquire the whole of the issued share capital of Thomas Crompton and Sons Ltd., Ashton-in-Makerfield, manufacturers of hinges, locks and builders' ironfoundry. The acquisition will be effected by means of share exchange and the consideration will be the issue of £300,000 ordinary stock and £200,000 second preference stock of Guest, Keen and Nettlefolds Ltd. Mr. R. Catlow and Mr. P. J. Tombleson will join the board of Thomas Crompton and Sons Ltd., and Mr. Catlow will be appointed chairman. Mr. John Crompton, whilst remaining a director of the company, will retire as chairman and in recognition of his services to the company will be appointed president. Mr. J. S. Crompton will continue as managing director of the company.

THE BRITISH OXYGEN COMPANY LTD., has announced that the assets and goodwill of its die casting business—formerly a division of Sparklets Ltd.—have been acquired by Fry's Diecastings Ltd. This transaction does not in any way affect the business of Sparklets Works as manufacturers of soda syphons, fire tubes and other small gas cylinders, inflation apparatus, &c., and B.O.C. retains its interests and rights in vacuum die casting patents. Machines and equipment will be transferred to the purchasers' factories over the next few months. Wherever possible employees of The British Oxygen Company Ltd., die casting department, will be offered alternative work within the Group. Some redundancy, however, is inevitable, the company states, and compensation based on length of service will be paid to those concerned.

Contracts

RICHARD COSTAIN (CONSTRUCTION) LTD. has started work on a contract valued at over £200,000 for Wiggins, Teape and Co. Ltd. It is for the construction of a new machine house of 16,900 square feet and an effluent treatment plant at Chartham Paper Mill, near Canterbury. The contract is due for completion early in 1962, and includes ancillary buildings, roads and services. The consulting engineers are W. S. Atkins and Partners.

BRITISH AIRCRAFT CORPORATION LTD. has announced that Braniff International Airways has placed an order for six BAC-111 short-range jet airliners, with an option for a further six. The airline operates in the United States, Central and South America, but most of its flying is on sectors of 250 miles or less.

AITON AND CO. LTD., Derby, has been awarded a contract from the Central Electricity Generating Board for high-pressure steam, re-heat and feed piping for the first supercritical steam pressure installation planned to be commissioned by the Board in the " C " station at Drakelow, Burton on Trent. The design conditions for the main steam are 4015 lb per square inch and 1110 deg. Fah. in austenitic stainless steel pipes of 9in internal diameter 2½in thick.

DAVY AND UNITED ENGINEERING COMPANY LTD., a member of the Davy-Ashmore Group, has secured a contract, worth approximately £1,000,000, for a 42in by 104in reversing blooming mill, complete with ancillary equipment, to be installed at the new integrated steelworks being built by the Park Gate Iron and Steel Company Ltd., Rotherham. The new mill will be the primary rolling unit of the works, and will roll ingots up to 5 tons in weight in carbon and rimming steels and certain low alloy steels. It will supply blooms ranging from 5in by 5in to 14in by 14in, to feed existing finishing mills and also new billet and narrow strip mills which Park Gate proposes to instal subsequently.

Miscellanea

OIL SEAL AND HIGH-PRESSURE HOSE FACTORY.—Super Oil Seals and Gaskets Ltd., Kings Norton, Birmingham, 30, has opened a new factory with a productive floor area of 270,000 square feet at Ty-Glas Road, Llanishen, Cardiff, to replace the factory of 60,000 square feet previously occupied at Western Avenue, Cardiff. When the Western Avenue factory was first opened ten years ago its whole production was concerned with oil seals and hydraulic packings; since that time a steadily increasing amount of capacity was devoted to the manufacture of high-pressure hose. The demand for hose is now such that more than half of the capacity at the new works is concentrated on its production. The 34-acre site of the new works will enable the existing productive floor area to be trebled as and when demand for the company's products increases.

DRAKE AND GORHAM LTD. ANNIVERSARY.—To mark the occasion of its seventy-fifth anniversary Drake and Gorham Ltd., the electrical, mechanical and hydraulic engineers is giving a series of four staff dinners in London, Cardiff, Manchester and Exeter, and the first of these dinners was held in London on October 17. An interesting booklet, issued in connection with the anniversary, describes how, in 1886, the late Mr. Bernard M. Drake borrowed £500 to start the business which was probably one of the first electrical contracting concerns in this country. He was later joined by Mr. J. Marshall Gorham, with whom he had been earlier associated in the employ of the Electrical Power Storage Company. The first objective of the new concern was to " bring the electric light to the stately homes of Britain," and with the passage of years the scope of the products and activities of the firm steadily increased. At the dinner in London last week, Mr. R. H. M. Drake, the son of the founder and present chairman and joint managing director of the firm, recounted some early experiences of his father who, he said, laid down the principles of quality and service which played an essential part in the growth and prosperity of the company in later years. This dinner was attended by about 150 members of the firm, and Mr. Drake was presented with a pair of period reproduction silver candlesticks by the staff foremen. An important part of the proceedings was in the presentations made to long-service members of the staff, and on this occasion gold watches were given to fourteen members who have completed between thirty-five and fifty years with the firm, pieces of silver to thirty-five with between twenty-five and thirty-five years service, and many others were given certificates for over fifteen years service.

Death

WE record with regret the death of Mr. A. H. Midgley, chairman and founder of Midgley Harmer Ltd., who died on October 1 at the age of seventy-nine. Mr. Midgley was actively engaged in the affairs of his company until the day of his death.

CONTINENTAL AFFAIRS

by Our Continental Editor

Italian Project for Preserving Abu Simbel

ONE of the consequences of the High Dam (Sadd-el-Ali) at Assuan will be the submersion of countless historic monuments and prehistoric sites in the gigantic lake which will be created. The first Assuan Dam, built in 1898–1902 and heightened in 1910–12 and again in 1930–33, raised the maximum level of the Nile from 93·76m above sea level to 106m, then to 113m, and finally to 121·1m. As a result, the important island temples at Philae, which lie about 2km upstream of the dam, are submerged for ten months out of twelve. As the High Dam lies approximately 7·5km upstream of the existing dam, these temples will not be affected further; indeed, the situation will be eased through the reduction in water level between the two dams to 110m above sea level. In order to render the temples accessible throughout the year and to preserve their structure from the water, it has been proposed to close off the site by a system of three dams constructed between the shore and outlying islands. The aim would be to hold the water level inside the dam at 100m above sea level. It would be necessary continuously to pump out the seepage.

High Dam

In its first stage, which has been under construction since January, 1960, and is scheduled to be completed by 1965, the new Assuan High Dam will impound the Nile to a maximum of 133m above sea level. When eventually the dam is raised to a crown height of 196m above sea level, the maximum water level will be 182m above sea level. This will create a lake of 4000km in area with a length of about 500km, of which, incidentally, 150km will be not in Egypt but in the Sudan. The 182m mark corresponds to the highest millennial flood ; at the that level, the total impounded volume is 130,000 cubic hectometres. The normal annual fluctuation is between 147m and 175m above sea level, comprising a useful volume of 70,000 cubic hectometres, with a buffer capacity above this level of 30,000 cubic hectometres, and an equal unutilised volume below.

Abu Simbel

When the construction of the High Dam first seemed likely to be carried into effect, there began an international movement, led by the Egyptian Department of the Musee du Louvre, to preserve as much as possible of the threatened antiquities. With the co-operation of the Egyptian Government, the UNESCO Documentation Centre on Ancient Egypt was brought into being in Cairo and moves were set afoot to obtain permanent records of as many objects as possible while they were still accessible and to remove or otherwise safeguard those considered to be of special importance.

In April, 1959, the Egyptian Government appealed to the Director-General of UNESCO for international financial and technical assistance to rescue the Nubian temples, and a world-wide campaign was launched.

From the beginning it was apparent that the most promising and at the same time technically the most difficult task was the preservation of the temples at Abu Simbel. These are situated approximately 200km south of the First Cataract and some way downstream of the second. There are two temples which are both hewn into the steep rock face of the left bank (Figs. 1 and 2).

The larger of the two, dedicated to Ammon and Harmakis, has the shape of a large rocky wall 40m wide and 32m high in front of which are four large seated stone figures representing the Pharaoh Rameses II. The interior of the temple, which is excavated entirely out of the solid rock, comprises a large hall divided into three naves by rows of columns. Figures symbolising Osiris stand with their backs to these columns. There follows the sanctuary, three small cells and other rooms with low ceilings. The walls are decorated with bas-reliefs representing the events of the Pharaoh's reign. The entrance faces east, so that the first rays at dawn penetrate some 63m right to the innermost wall where they fall on the statue of the sun god

Fig. 1—The Great Temple at Abu Simbel, with statues representing the Pharaoh Rameses II (1300-1233 B.C.)

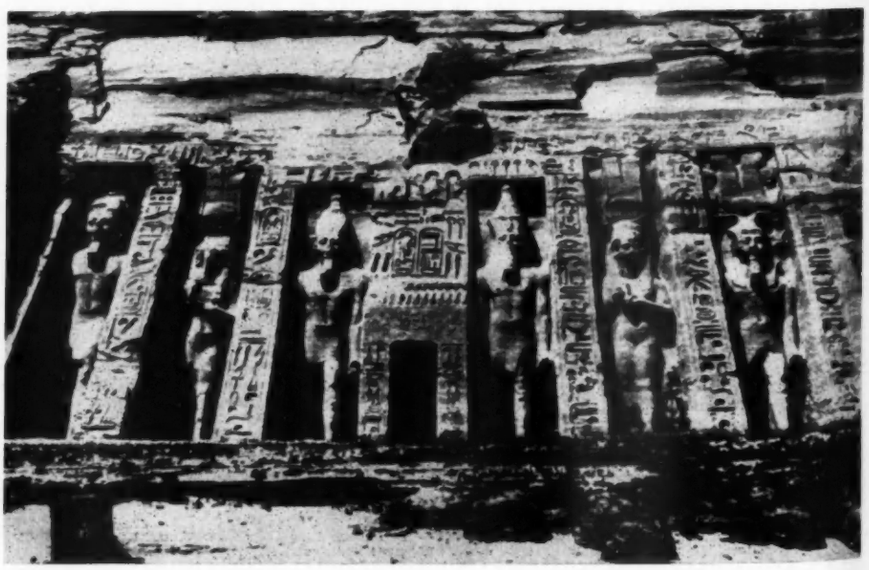
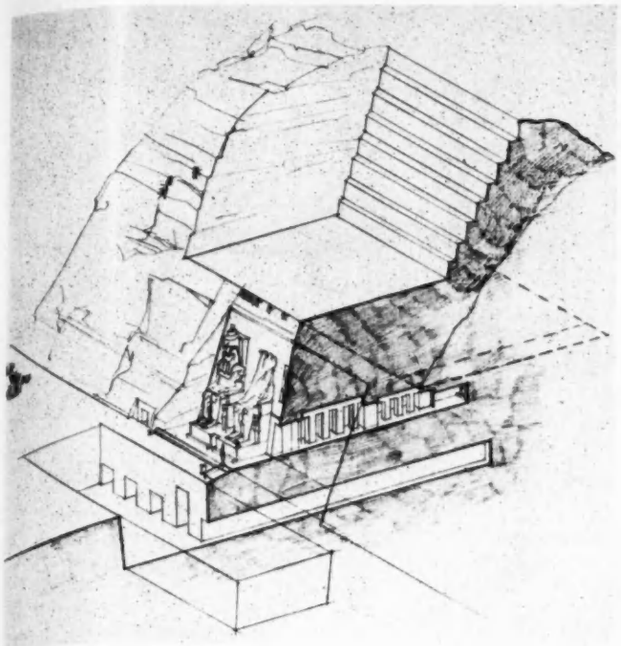
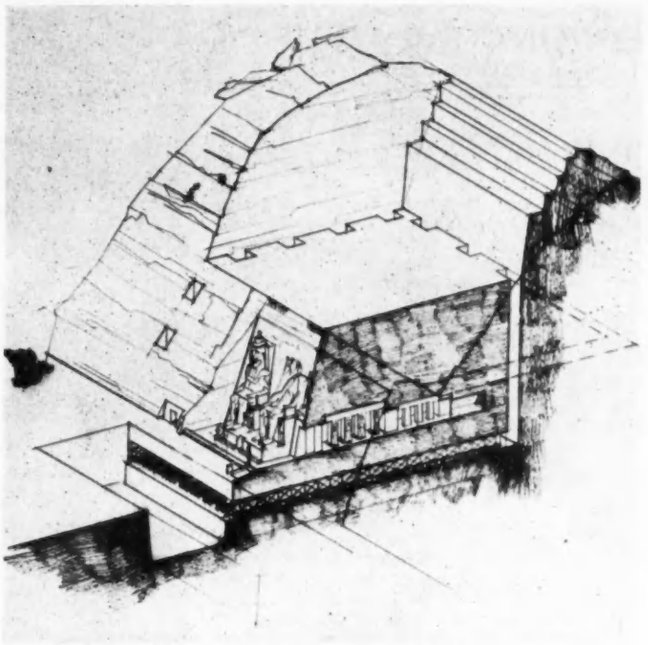


Fig. 2—The Small Temple at Abu Simbel, dedicated to Hathor. Like the neighbouring Great Temple, it is carved from the solid rock. The projected rise of 62m in the level of the Nile threatens to submerse both Temples permanently





Figs. 3 and 4— (Left) After removing the mass of rock above the Great Temple in order to reduce the weight, the space underneath is excavated in stages for the insertion of a concrete support structure. An identical procedure will be followed in the case of the Small Temple. (Right) Vertical shafts are sunk at the sides for inserting lateral guides

which they appear to animate and cause to move in a direction opposite to that of the sun, a most striking effect.

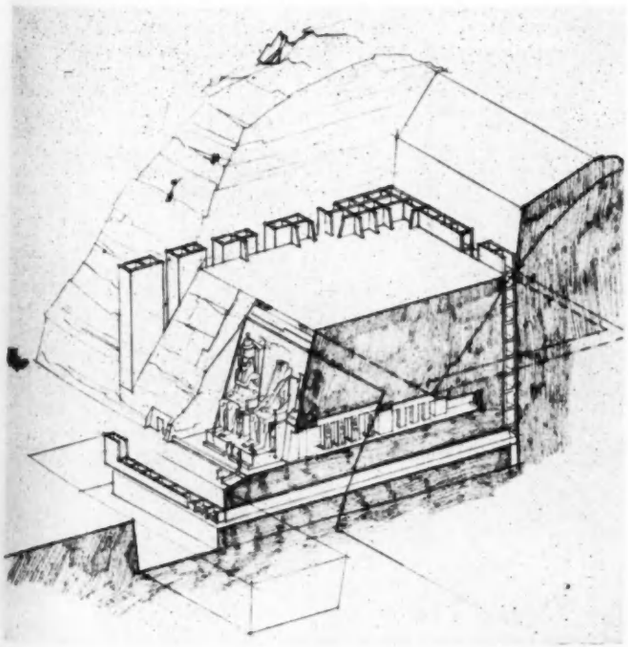
The smaller of the two temples is dedicated to Hathor. Its façade comprises six giant statues standing between large inscribed columns, three on either side of the entrance. The temples were built in the lifetime of the Pharaoh who lived from 1300 until 1233 B.C.

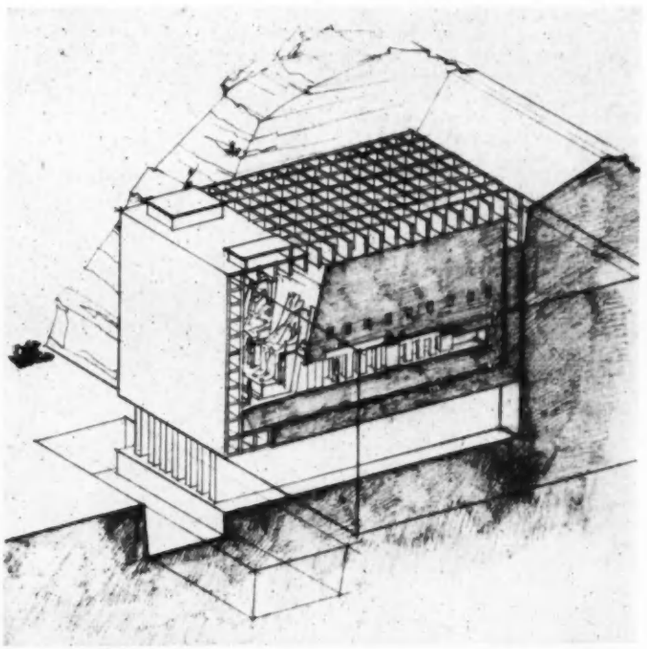
The river level at this point will eventually be raised by as much as 62m, which would cause the temples to disappear completely. Four proposals have been made for their preservation. One scheme envisaged the construction of two concrete arch dams, one in front of each temple. A second project involved enclosing both temples by a single large arch dam ; a third proposal favoured an earth dam. Finally, there was the idea of raising of the temples bodily to a height above the final water level. In particular, the proposal for an earth dam was studied in some detail by Studio Coyne & Bellier, of Paris. It was to have had a crown length of 1500m and a height of 65m. This would have placed the temple entrances at a distance of approximately 190m from the dam. An artificial lake would have been left in front of the temples, with a water level approximately the same as before. Seepage was to have been collected and pumped back into the river.

The fourth solution, already mentioned above, is based on quite different principles. It was put forward by the group Italconsult-imprese Italiane All'Estero (Impresit)–Impresa Ing. Lodigiani. This project, based on a scheme advocated by Professor Gazzola, consisted in raising both temples above the future water level. In spite of its obvious technical difficulties this would seem to offer a number of advantages over the installation of a cofferdam. Raising the temples above the waterline would permanently safeguard them from the effects of moisture which in the case of a dam might seep into the rock in some unforeseeable way. It would also obviate the danger that at some future period the pumping stations might fall into disuse which would drown the space enclosed by the dam.

Finally the solution is claimed to be superior from the aesthetic angle, in that it leaves the view unobstructed and the light conditions inside the temples unchanged. The total cost of the raising operation, including all preparatory and subsidiary work, has been estimated at 42,000,000 dollars, while the cost of afterwards restoring the surroundings is put at 15,000,000 dollars. This of course represents a final figure without entailing any future expenditure on the score of maintenance or operation.

It is considered that the whole of the work





Figs. 5 and 6—(Left) Insertion of the guide structures. (Right) Completed cradle

CONTINENTAL AFFAIRS *(Continued)*

can be carried out in six years. For each of the two temples, the procedure may be considered to fall into ten stages.

Work in such a remote locality naturally entails elaborate preliminary installation, such as housing for the staff, an electric power house, an airstrip, roads, landing stages on the river, &c., besides the usual equipment of a building site.

It would next be necessary to build some form of protection from the Nile waters in front of each temple, and behind it to construct an adit to the base of each block which is to be raised. The rock underneath the temples would at that stage be waterproofed by means of injections of grout.

The overburden would then be cut away as much as possible in order to reduce the weight (Fig. 3).

There would follow the installation underneath, at the sides, and above each block of rock, of prestressed concrete structures in which the block would rest when separated from the hillside. This would be done in successive stages involving the driving of a number of galleries and shafts spaced at suitable intervals in which the prestressed concrete structures would be inserted (Figs. 4 and 5).

A concrete baseplate would then be installed, section by section, underneath the cradle. The whole mass, amounting to some 300,000 tonnes, would then be isolated from the hillside and rest in the cradle.

The next step would be the installation of some 300 special hydraulic jacks, each capable of exerting 1500 tonnes. The rock mass would then be raised evenly, 2mm at a time, by applying hydraulic pressure to the jacks. The evenness of the lift is to be checked electrically by means of an artificial horizon of mercury. This would make it possible to detect the least deviations of each jack and correct it at once. Every 30cm of lift the space underneath the permanent support structure would be concreted (Fig. 6). Once the lift had been completed, the rock would be set down on its final supports of reinforced concrete and the jacks removed. Finally, the wall of the cradle projecting beyond the front of the temple would be demolished and the adjacent hillside and the top restored in a manner resembling as far as possible the present state.

The elaboration of this project was carried out by Professor Gustavo Colonetti and Riccardo Morandi, in collaboration with the architect, Professor Pietro Gazzola.

The examination of the proposals for the preservation of the Nubian monuments which were submitted was referred by the Egyptian Government to an international consultative commission of twelve experts. The French and Italian proposals regarding Abu Simbel were referred to a five-man international committee which came out in favour of the Italian project. Last January, their decision was endorsed by the Consultative Commission.

30-ton mains-frequency crucible furnace for the smelting and holding of iron at a temperature of 1450 deg. Cent.

Mains-Frequency Crucible Furnace

A 30-ton mains frequency crucible furnace for the melting and holding of iron recently commissioned at the Swedish ironworks AB Akers Styckebruk has now been followed by a second similar unit. The maker is ASEA, Västeras, Sweden, and it is claimed that these are the largest units of their kind in existence. The problem with furnaces of this size has been to design a suitable crucible with a sufficiently durable lining. This is stated to have been solved after extensive research work, the first furnace having now been in operation for over seven months without it being necessary to change the crucible. During this period about 7000 tons of iron have passed through the furnace, the temperature of the melt being 1450 deg. Cent. Our illustration shows one of the two induction furnaces on its way to the ironworks. Because of the height of the load, which was 4·5m, overhead lines at level crossings had to be removed to let it pass.

Research Reactor for Graz

The Association for the Advancement of Nuclear Energy, Graz (Austria), has placed an order with Siemens-Schuckertwerke A.G., Berlin-Erlangen, for a reactor of the "Argonaut" design. This will have a continuous rating of 1kW (electric) and will be used for research and training.

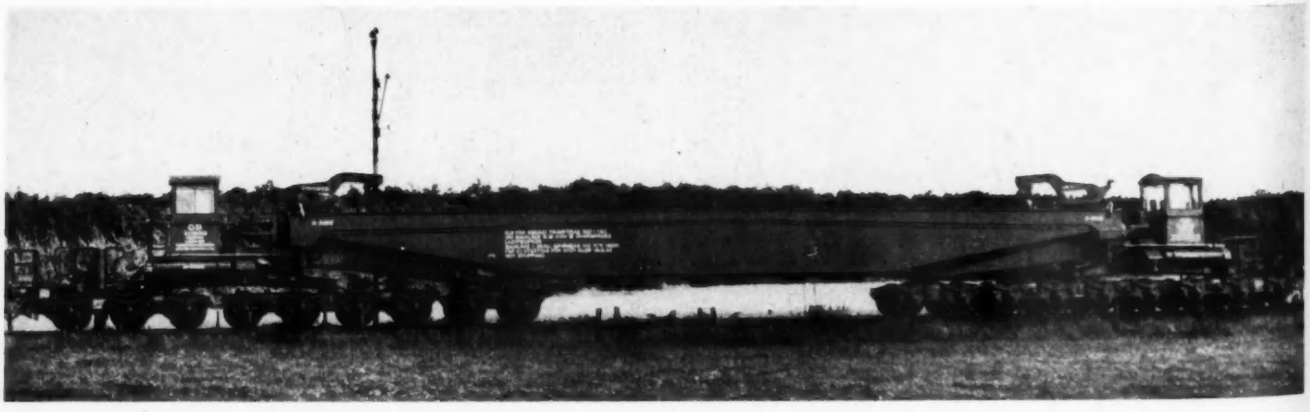
Railway Wagon for 260-ton Loads

Our accompanying illustration shows a railway wagon for extra-heavy special loads which was delivered to the Swedish State Railways on August 16. It has a loading capacity of 260 tons as compared with 173 tons in the case of the previously biggest wagon.

The bogie wagon has been given the designation "Q 51" and has an overall length of close on 40m, weighs 100 tons and is equipped with eighteen axles for a load of 20 tons each.

This new wagon is stated to be a highly flexible unit which can negotiate curves down to 80m radius. The bogie design is such that it is possible to exchange the Swedish wheel-sets for wheels adapted to wider gauge if needed; this change can be made while the wagon is fully loaded.

To diminish the risk of tipping on superelevated bends, the saddles with girders and load can be moved off centre by up to 200mm towards each side. This is done by means of compressed-air motors. The wagon, built by Chr. Olsson i Falkenberg AB, Falkenberg, Sweden, is equipped with dual manoeuvring cabins from which it is possible to maintain telephone contact with the locomotive and with a special escort car.



Eighteen-axle wagon for loads up to 260 tons. The wagon is nearly 40m long and weighs 100 tons. On curves, the load can be moved off-centre to preserve stability

Polyester resin level-crossing gates with internal illumination in operation at the Spaansebrug near Rotterdam

Polyester Resin Crossing Gates

Glass-fibre polyester laminates lend themselves to the economic construction of a wide range of components, and for some years the production of such parts has been growing in importance at the Utrecht Works of Werkspoor N.V. One of the latest applications is railway crossing gates which are supplied either transparent or opaque. The transparent version is intended to be used with internal illumination. A spotlight with a special bulb is directed along the hollow inside, resulting in the effect seen in the accompanying illustration.

The gates are hexagonal in section, taper towards the top, and are made in lengths up to 9m. Construction is in two halves, using the same mould, the halves being glued together subsequently using polyester resin and glass-fibre matting. Red and white sections, each 50cm long, have the colour incorporated in the material. The material does not rust or corrode and does not need painting. Its light weight, it is claimed, means that a mechanism of lighter and cheaper construction can be employed. Gates provided with internal illumination obviate the use of reflectors and external warning lights.

[Reply Card No. 1315]

Electro-Magnetic Control Valve

The firm Weisheit Regeltechnik Essen, Bismarckstrasse 55, has put on the market a range of electro-magnetic control valves for gases, vapours, or liquids. The valves are designed to be operated by automatic controllers or final control elements, and the rate at which corrective action is initiated can be infinitely varied to suit the load in the controlled system and its rate of change. No auxiliary energy source such as compressed air, &c., is required so that installation and running costs are low. The valves are single-seat models with opening or closing action, with inside diameters from 25mm to 200mm. Leading dimensions correspond to German standard specifications. For pressures up to 16 kg per square centimetre gauge the valve bodies are cast iron, for higher pressures up to 64 kg per square centimetre they are steel. Special materials are used for corrosive media. In the case of valves for liquids, the closing member is a solid or slotted body having a linear or equiproportional characteristic, while a special design is used for compressible media so as to obtain the characteristic required. The valve stem is sealed by a self-lubricating packing, and provided with cooling or heating fins in cases when the medium is above 180 deg. Cent. or below −10 deg. Cent. Explosion-proof ualves are also available.

[Reply Card No. 1316]

Automatic Profile Welder

We have received details of a machine which is now being marketed, claimed to be the first of its kind to produce beams of various profiles by an automatic welding process. Its operation is stated to be a radical departure from the time-honoured rolling process, since beams are fabricated from plate pre-cut to the required final thickness and length, and sections are then automatically welded together to form the desired profile. I-beams, U-beams and T-profiles, as well as special profiles, can be produced with predetermined web heights and flange widths that remain constant. The machine can also be adapted to weld tubes. The machine, shown in our accompanying illustration, was designed by Pullmax AB, Gothenborg 1, P.O. Box (agent : Pullmax (Great Britain), Ltd., Blackpool). It consists basically of three main sections : the feeder, two or four automatic welding units, and corresponding welding generators.

The feeder is an automatic table built on a heavy bottom frame and operated by electric motors, variators and hydraulic pressure cylinders. During welding, beams are conveyed by hardened, heat-treated feed rollers. One side of the feeder is adjustable to permit the welding of I-beams with heights between 12in and 60in. Flats for flanges can be used with dimensions between 2in and 20in. The feeding speed is continuously variable between 0ft and 5ft 6in per minute.

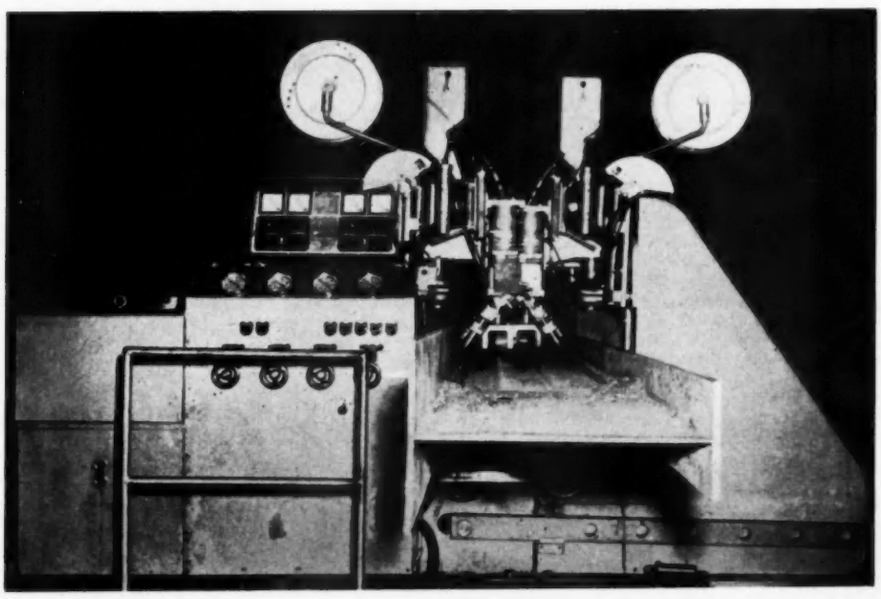
The welding units have fully submerged arc welding heads rated at 900A and handle wire sizes from 0·031in to 0·25in. Operated by a constant voltage d.c. and rated with a capacity up to 900A, the arc welders are claimed to be excellent for fillet welds in submerged arc welding and butt welds. The production and use of welded beams are expected to do much towards simplifying problems of manufacturing costs, material handling and storage. It is stated that a welded beam offers a distinct saving in weight compared with rolled beams of the same section modulus. It is claimed that for some welded profiles savings in production cost up to 40 per cent compared with rolled beams can be achieved.

[Reply Card No. 1317]

European Trade

The increase in Europe's share of total world trade in 1960 according to a recently published E.C.E. Report* was entirely due to the rapid expansion of western European trade : the share of eastern Europe even fell slightly. The mounting importance of intra-European trade as a share of world trade is the more remarkable when intra-western-European trade is considered alone. Between 1957 and 1958 the share of intra-western-European exchanges in total world trade had increased from 20·0 per cent to 20·4 per cent ; between 1959 and 1960 this share rose from 21·1 per cent to 22·9 per cent. The report contains chapters on : Europe's place in world trade ; recent developments in western Europe's trade ; the trade of eastern European countries ; and trade between eastern and western European countries.

*"Economic Bulletin for Europe," Vol. XIII, No. 1. Prepared by the Secretariat of the United Nations Economic Commission for Europe (E.C.E.) *Geneva* ; European Office of the United Nations, Geneva, Switzerland, or H.M. Stationery Office, P.O. Box 569, London, S.E.1. Price 5s.



Automatic profile welder

THE AMERICAN SCENE

By Our American Editor

Dedication of Brookhaven Alternating Gradient Synchrotron

The dedication took place at the Brookhaven National Laboratory, Upton, New York, on September 13 of the most powerful particle accelerator in the world; it has accelerated beams of protons to an energy of 33,000 MeV. The machine is known as the Alternating Gradient Synchrotron (A.G.S.) and employs a new principle of focusing strong magnetic fields, discovered at Brookhaven. The heart of the accelerator is an underground circular magnet 843ft in diameter comprising some 4000 tons of iron and 400 tons of copper.

THE Alternating Gradient Synchrotron (A.G.S.) went into operation at the Brookhaven National Laboratory, at Upton, Long Island, New York, in July, 1960 and was officially dedicated on September 13, 1961. It has already produced beams of protons at an energy of 33,000 MeV, which is believed to be the highest energy ever attained by a particle accelerator. It is particularly appropriate that the new machine is situated at Brookhaven, for it was there, in 1952, that the principle of strong focusing of particle beams was discovered. If this discovery had not been made, the magnet for an accelerator capable of reaching the desired energy would have been prohibitively large and expensive. The completion of the A.G.S. represents an important step forward in American studies of nuclear forces and the properties of sub-nuclear particles. It will enable scientists in the United States to study nuclear interactions at energies about five times greater than ever before possible in that country.

The address of dedication was delivered by Dr. Leland J. Haworth, a member of the Atomic Energy Commission. Dr. Haworth, who was Director of the Brookhaven National Laboratory from 1948 until his appointment as a Commissioner last April, has given vigorous leadership to the A.G.S. project from its inception. He served as chairman of Brookhaven's accelerator development department, which was responsible for the design and construction of the A.G.S. until November, 1959, when the present chairman, Dr. G. Kenneth Green, was appointed to that position. The dedication ceremonies followed the 1961 International Conference on High Energy Accelerators, which was held in New York City and Brookhaven in September. The conference was sponsored jointly by the International Union for Pure and Applied Physics, the U.S. Atomic Energy Commission, and Associated Universities, Incorporated.

Following preliminary design studies started in 1952, the A.G.S. was authorised and funds were allocated by the U.S. Atomic Energy Commission in early 1954. Construction was started in late 1955, and digging for the half mile circular trench to house the magnet tunnel began in January, 1956. In November, 1956, the staff of the accelerator development department was able to move into the newly-constructed A.G.S. service building, which included electronics and machine shops and laboratories. While design work proceeded, the tunnel was cast and covered, and the original target building was constructed. During 1958 the magnets began to arrive from the manufacturer; eventually, they almost filled the target building while undergoing the necessary testing prior to installation in the ring. The magnets were soon followed by "linac" tanks, the magnet power supply, radio-frequency parts, vacuum system components, wires, pipes, and all the other items comprising a big particle accelerator. The magnet was first energised from its power supply in March 1960. In the following month the "linac" accelerated protons. Precise alignment of the magnet was completed, and the first attempt to obtain a full revolution of the particles was made on May 17, 1960. A week later the beam was injected, the inflector was pulsed, and a circulating beam was observed to make more than 100 revolutions. A series of adjustments was made on the radio-frequency system and the "linac," (linear accelerator) and the first acceleration trials were attempted on July 22, 1960, at which time the beam occasionally accelerated to the phase transition at 7000 MeV. Further adjustments were made on the radio-frequency system, and on July 29, 1960, protons were first accelerated to an energy somewhat over 30,000 MeV.

In the ensuing year the A.G.S. has been improved, auxiliary equipment has been installed, and the research programme begun. The machine can now deliver a peak energy of 33,000 MeV. Its normal operating energy is 30,000 MeV, at which level it can deliver a pulse every 2·4 seconds. The pulse rate can be increased to 1·6 seconds at 20,000 MeV and 0·8 seconds at 10,000 MeV. An intensity of 3×10^{11} protons per pulse was reached within a year of initial operation. The total cost of the A.G.S. and its buildings is approximately 32,000,000 dollars.

An over-all plan of the Brookhaven A.G.S. complex is shown in Fig. 1 while Fig 2 is an aerial view of the finished construction site. The circular tunnel housing the magnet ring is covered with an earthen dyke as a shielding measure. At the lower right edge of the ring is the "linac" building, which houses the injection system for the synchrotron. The large

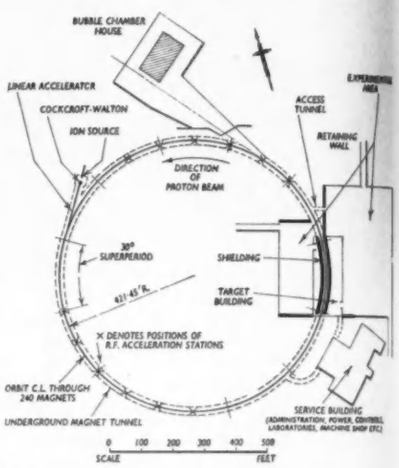


Fig. 1—Plan of Alternating Gradient Synchrotron at the Brookhaven National Laboratory

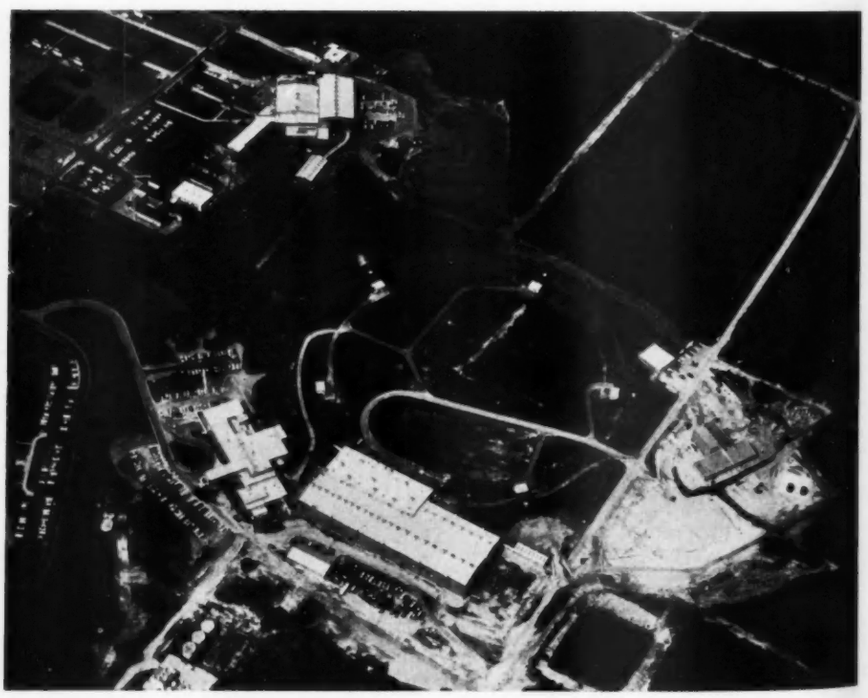


Fig. 2—Aerial view of the completed A.G.S. site at Brookhaven

Fig. 3—Point of injection of 50MeV proton beam, passing from the "linac" through focusing lenses and steering magnets into the orbit of the magnet ring

square structure astride the front side of the ring is the target building, where the experimental equipment for high-energy physics research, utilising the synchrotron's proton beam, is installed. To the left of it is the laboratory and office area. The magnet tunnel opening is about 18ft square, and the ring is half a mile in circumference. The inward projections in the upper part of the tunnel support the rails of two 20 ton travelling cranes that span the tunnel for handling the magnets and other equipment. The tunnel is covered with earth, for radiation shielding and to aid the air-conditioning system in keeping the interior temperature constant to ±2 deg. Fah.

The operation of the alternating gradient synchrotron may be described by following the protons from source to target in Fig. 1. The protons are the nuclei of the most common isotope of hydrogen. Hydrogen gas is supplied to a cold-cathode discharge at a pressure of about 1/20,000 of an atmosphere in the ion source shown at the upper left of Fig. 1. Protons from the ionised gas in the discharge pass through a small orifice 1mm or 2mm in diameter in the cathode, whereupon they are accelerated through 750 keV by a Cockroft-Walton generator. The 750 keV protons are then accelerated to 50 MeV in the "linac," illustrated in Fig. 3. In the "linac," the protons pass through 124 drift tubes of varying length and diameter placed along the axis of a copper-lined tank about 1in in diameter and 110ft long.

The protons are "bunched" in the beam like beads on a string, and the spacing of bunches increases with velocity through the "linac." Each bunch experiences a forward or accelerating electric field in the gap between drift tubes. While the bunch is passing at constant velocity through the axial hole within the drift tube, the cavity oscillation reverses the electrical polarity of the tubes so that the bunch is again subjected to an accelerating field by the time it reaches the next gap. By proper choice of the voltages, tube lengths, and spacings, bunches are accelerated simultaneously at alternate gaps all along the "linac." The peak gap voltages vary from 116kV at the beginning to 890kV at the end, and the cavity requires 3MW of power at 200 Mc/s during the acceleration. The oval shaping of the drift tubes materially reduces the energy required to excite the electromagnetic oscillations within the cavity to given gap voltages and permits higher voltages to be used without electrical breakdown. The beam is injected at 50·8 MeV into the ring, being conducted from the "linac" into the main synchroton ring through an elaborate injection system of debunching, deflecting, focusing, and monitoring gear. At injection into the ring, the beam is about 1·7in diameter and comprises several milliamperes of protons with a total angular spread of 5 milliradians (diverging horizontally and converging vertically) and an energy spread of about 0·1 per cent.

In the "linac" each proton passes each accelerating gap only once. By deflection into circular orbits the protons may be made to pass many times through each acceleration station around the ring. There are twelve radio-frequency acceleration stations around the ring at the points marked *X* in Fig. 1. Each station consists of a double tunable radio-frequency cavity, which will impose accelerating electric forces on the proton bunches at each passage by means of a pair of accelerating gaps about 4ft apart in the vacuum chamber wall ; the gaps are made vacuum-tight with ceramic insulators. At each passage, each station accelerates the protons by 8000V, hence the protons gain about 96 keV from the twelve stations for each transit around the ring. On this basis, the protons must go around the ring 260,000 times, or 130,000 miles, to gain 25,000 MeV in energy. As the energy increases, the velocity of the protons increases rapidly at first and then more slowly as the protons approach the velocity of light. Due to the velocity increase, the transit time of each proton bunch around the ring decreases. Therefore, the frequency at the accelerating stations must be increased so that the protons will arrive at the gaps in the right phase to experience a forward or accelerating impulse. The cavities are tuned to resonate at the right frequency by adjusting the permeability of the ferrite rings with which the cavities are loaded. The magnetic permeability of a ferrite is a function of the degree of constant magnetisation which may be simultaneously impressed on it by a direct current. By the ingenious double-cavity arrangement used, the d.c. saturating bias may be superimposed on the radio-frequency a.c. in the cavity walls.

The cavities are operated on the twelfth harmonic of the revolution frequency, and there are twelve equally spaced bunches of protons circulating around the ring during acceleration. Since the protons are accelerated from less than one-third of the velocity of light to within a fraction of 1 per cent of light velocity, the frequency of the accelerating cavities increases, in proportion, from 1·40 to 4·46 Mc/s. To keep them in step, the power amplifiers from the twelve double cavities are driven either in phase or 180 deg. out of phase from a common driving source. The exact frequency and phase of the driving source are governed by the revolution frequency and radial position of the proton bunches, as sensed electrically by suitably placed "pick-up" electrodes within the vacuum chamber.

The magnets of the machine perform two functions : guiding the proton beam into a circle and focusing the beam. The deflection of the protons into a circular path is accomplished by the force exerted on a charged particle moving across a magnetic field. Each of the 240 magnets around the A.G.S. ring deflect the protons by about 1·5 deg., or 360 deg. in all to complete the nearly circular path. The reference circle is 842·90ft in diameter. The physical length of

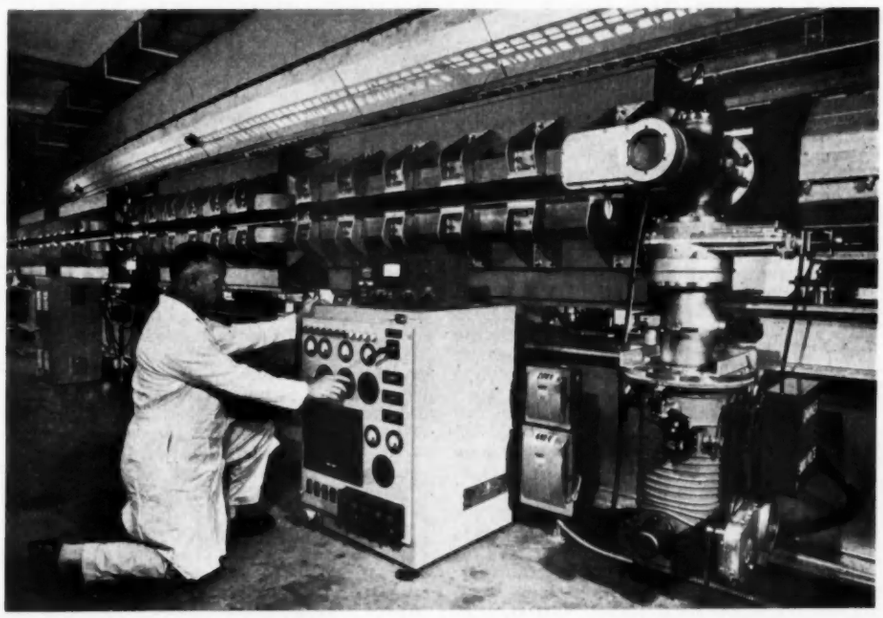


Fig. 4—One of forty-eight titanium evaporation pumps, with its adjacent control console, for maintaining the high vacuum in the synchrotron tube

THE AMERICAN SCENE *(continued)*

the magnets occupies about two-thirds of the circumference, the rest being available as straight sections between magnets for other equipment, such as acceleration stations and vacuum pumps, and equipment for injection, targeting, ejection and the like.

A nearly elliptical vacuum chamber, just over 6½in by 3in inside, is centred in the gap between the magnet poles on the " aperture centre line," which lies 5·25in from the open side of the poles, where their vertical separation is 3·50in. A pressure of 10^{-6}mm Hg is maintained in the whole vacuum chamber by forty-eight titanium getter-ion pumps, as shown in Fig. 4, which are distributed around the ring to prevent undue loss of protons by collision with residual air molecules. The chamber is made of non-magnetic " Inconel-X " sheet, 0·078in thick, which offers relatively high electrical resistivity against eddy currents.

As the energy of the protons increases during acceleration, their momentum p also increases. To hold the orbits to the over-all ring curvature set by the vacuum chamber, the deflecting magnetic fields B must increase in proportion to p. A 100-fold increase in B is required in a little over a second following injection at B-120 gauss. The magnets are energised by passing electric currents through the coils. To make the fields rise uniformly around the ring, the magnet coils are connected in series so that the same current will flow in all magnets. Actually there are two such series circuits, each containing two of the four pancakes on each magnet. The currents flow in opposite directions around the ring in the two series circuits in order to avoid undesirable magnetic effects of a single turn around such a large ring. Furthermore, a pulse-shaping saturating indicator is included, and the two series circuits are connected in parallel across the power supply, which consists of an ignitron-rectifier, twelve-phase 36,000kVA generator, a 47-ton flywheel, and a 5500 h.p. motor driven from 13·8kV, 60 c/s a.c. mains.

For top-energy protons the accelerating pulse is repeated twenty times a minute ; it consists of a current rise from 0A to 6500A in about 1¼ seconds, followed by a decrease to zero in about a second before the beginning of the next pulse. Each pulse is started by firing the ignitron rectifiers in the proper phase ; this applies about 5000V to the magnet circuit. The magnet current begins to rise against the inductance and resistance of the magnet circuits. As the current rises through 45A the protons are injected from the " linac," and ring accelerations begins and continues until the magnet current reaches about 145 times the injection value. At top current about 14,000,000 joules of energy are stored in the magnetic field of the magnets, and over 10,000,000W are being turned into heat in the resistance of the magnet coils. The heat is carried away by cooling water flowing in the axial ⅛in hole in the coil copper. To bring the magnet current down to zero again, the magnetic-field energy is drawn off into the flywheel by inverting the phase at which the ignitrons are fired so that the magnet current flows against the electromotive forces generated in the alternator, causing it to act as a motor and thus speeding up the flywheel. The rotational speed of the rotating parts varies from 815 to 875 r.p.m. during the pulse, and the net electric power demand is only that required to supply the losses, i.e. enough for the 5500 h.p. motor to maintain full speed before the start of each pulse. This ingenious scheme for handling the inductive energy stored in the magnet was originally developed for the Cosmotron, whose power supply is almost as large as that required for the A.G.S., and it has proved eminently satisfactory.

Most of the initial experimental work has been conducted in the target building. This is a large rectangular structure, 100ft wide by 250ft long and 40ft high, through which the magnet passes. A 40-ton overhead travelling crane spans its width, and 14,000 tons of heavy concrete shielding blocks cover that portion of the magnet ring that intersects the building. An extension that will approximately triple the available area is being built. At first, target substances were suddenly inserted into the beam in the vacuum chamber to intercept the circulating proton beam, thus producing the reactions to be studied by means of the radiations emitted. Fig. 5 shows such an insertion mechanism. Ultimately, it is planned to deflect the proton beam out of the vacuum chamber. An external beam greatly enhances the usefulness of the machine,

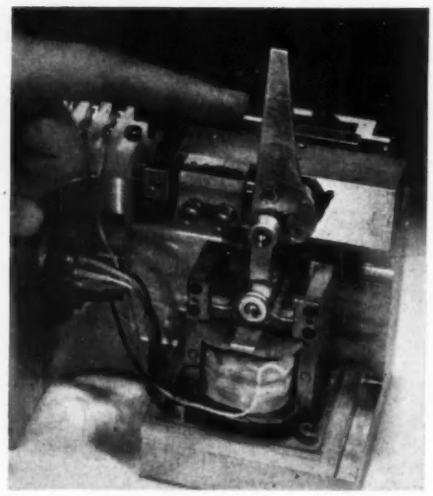


Fig. 5—Remotely controlled mechanism for the insertion into the proton beam of the target, which may be aluminium, beryllium or graphite

since it is more accessible and since many experiments can then be installed simultaneously along the path of the beam, and the direct beam used by each as needed. To provide for the emergence of selected experimental beams, channels can be formed through the shielding by re-arranging small plug blocks specially provided for this purpose at the level of the particle beam. As additional shielding for stray radiations from the A.G.S., the entire tunnel housing the magnet ring has been buried beneath a 10ft layer of earth, except that section which passes through the target building.

In the spring of 1962, a long slot will be cut in the wall of the tunnel to supply particles to the North Experimental Area, where the Brookhaven 80in bubble chamber will be situated. It is hoped that in the following year construction will begin in this area of a target building to cover more complex beam-handling equipment for this large bubble chamber and to house experiments which cannot be accommodated in the existing East experimental area. The A.G.S. is currently running on two shifts, five days per week. As soon as personnel and funds are available, it will be operated on a three-shift basis, since requests for experimental time far exceed the available operating time.

Most experiments performed at the A.G.S. will be studies either of particle production or of particle interactions. Some kinds of interactions, if not thoroughly understood, are at least being classified, and rules of behaviour of subnuclear particles are beginning to emerge. But predictions from theory of particle production processes at A.G.S. energies were so uncertain that the first experimental programme at the A.G.S. was a survey of the kind and distribution of particles ejected from a target under proton bombardment at various energies up to 30,000 MeV. These studies used Cerenkov counters whose peculiar properties include the ability to determine the particle velocity very precisely. The results, in combination with information about the effect of a magnetic field on the particle, made it possible to identify the product particles.

The next major effort in the experimental programme was observation of the tracks left by the new particles in liquid hydrogen in a 20in bubble chamber. Over 200,000 photographs were taken during this run. Attention was then again turned to counter experiments, and a preliminary study of interactions of antiprotons and K-mesons with protons was undertaken. On completion of this study, the beam was shut down for several weeks to permit extensive rearrangement of components for the purpose of setting up a separated beam of antiprotons to be studied in more detail in the 20in bubble chamber. After this is complete, another rearrangement will be made in preparation for an attempt to study neutrino interactions. While these major experiments are in progress, secondary " parasitic " experiments are carried on in other beams from the same or other targets. At times as many as four parasitic experiments have been attempted simultaneously with two primpary experiments whose requirements set the operating parameters for the A.G.S.

Much work remains to be done in fitting new devices to the machine and adapting its performance to new experimental requirements. Many years of work lie ahead for the A.G.S. and its staff ; it is expected that its useful life will span at least two decades. Yet already some of its designers are beginning to think in terms of another ring ten times, perhaps twenty, possibly even thirty times as big as the A.G.S.

Production of Ultra-High-Purity Crystals of Tungsten

A major step forward in the tungsten field, which may have an important impact on the United States space programme, has been announced by the Westinghouse Electric Corporation, of Bloomfield, New Jersey. The firm has developed a practical method to produce large single crystals of tungsten of extremely high purity and density, and tungsten rods 10in long and 0·2in in diameter are now being produced as single crystals. Special refining techniques have been developed which even make it possible to grow these ultra-high-purity crystals in predetermined crystalline forms with a purity of up to 99·9975 per cent. These large crystals of tungsten are big enough to permit the commercial fabrication of small parts from them.

Tungsten is usually considered a hard brittle metal, very difficult to machine or fabricate. However, the ultra-pure single crystals are actually ductile, even at temperatures as low as minus 330 deg. Fah. The development of the large single crystals of tungsten was the result of the need for more knowledge about the fundamental properties of tungsten, which is a key component in the products of the lamp, electronic and missile industries. Since tungsten metal, suitable for such studies, was not available, Westinghouse engineers designed unique zone melting equipment using the electron beam principle of heating in order to produce bigger and superior crystals. However, to attain the ultra-pure single crystals, it was necessary first to develop a process for making special high-purity tungsten ingots. These high-purity ingots are then used in the zone melting process as the starting material from which the single crystals are grown.

Ironically, after the extreme-high-purity tungsten crystals were attained, it was found that existing analytical techniques were not adequate to obtain precise measurements of gases and metallic impurities when they are present in only a few parts in a million. As a result, advanced methods of optical spectroscopy, vacuum fusion and neutron irradiation analyses were developed to verify the infinitesimal amounts of impurities.

BRITISH PATENT SPECIFICATIONS

The dates printed are those of application and publication on completion. Copies of specifications may be obtained at the Patent Office Sales Branch, Southampton Buildings, Chancery Lane, W.C.2, 3s. 6d. each

AIRCRAFT

878,721. January 12, 1960.—HELICOPTERS, Power Jets (Research and Development) Ltd., 25, Green Street, London, W.1. (*Inventor : Ronald Andrew Shaw.*)

This invention relates to helicopters in which the rotor is driven by jet streams discharged from nozzles at or towards the rotor blade tips. Conventional helicopters, that is, helicopters in which the rotor provides both the lifting and the propulsive forces, suffer from the disadvantages of relatively limited endurance, range and flight speed, and various proposals have been put forward for improving the performance in these respects. In particular, one helicopter is known which has stub wings which in cruising flight are capable of supporting part of the weight of the machine. The helicopter is powered by gas turbine engines which on take-off and landing and in hovering flight drive auxiliary compressors which supply compressed air through the rotor blades to jet propulsion units at the blade tips. Fuel is burnt in these tip jet units and the resultant hot gases are discharged as propulsive jet streams to drive the rotor. In cruising flight the engines are disconnected from the auxiliary compressors and the whole output of the engines is used to drive propellers to produce forward thrust on the helicopter. The stub wings then take over part of the weight of the helicopter, while the rotor is partly unloaded and is allowed to auto-rotate. The helicopter referred to includes clutch mechanisms for providing connections between the engines and the auxiliary compressors, and also reduction gearing through which the engines drive the propellers. These components are thought to involve a considerable weight penalty, and in addition a complicated control system is unavoidable. Further, the noise emitted by the jet streams is increased by the necessity for burning fuel in the tip jet units on take-off and landing and when hovering. It is an object of this invention to provide a modification of the helicopter in which the weight penalty, complication and noise is reduced. The helicopter has a lifting rotor with jet units mounted at or towards the rotor blade tips for driving it, a ducted fan jet propulsion system to produce forward thrust and a gas producer which can be connected to supply compressed gas either to the rotor jet units or to drive the ducted fan. The gas producer is preferably an auxiliary compressor driven by a gas turbine. The ducted fan system may comprise turbine rotor blades in driving connection with the ducted fan rotor blades and driven by compressed air supplied by the auxiliary compressor. In a helicopter according to the invention the gas producer, i.e. the auxiliary compressor is always in use, to drive either the lifting rotor or the ducted fan, and so a mechanical clutch is not required. The use of a ducted fan system rather than a propeller eliminates the necessity for reduction gearing. It should be possible to drive the lifting rotor by relatively cold jet streams of air, that is, without burning fuel in the rotor jet units, so that jet noise is reduced. Some specific embodiments of the invention are described by way of example with reference drawings.—*October* 4, 1961.

SHIPS

878,027. May 21, 1959.—ICEBREAKERS, Franz Hitzler, proprietor of J. G. Hitzler Schiffswert und Maschinenfabrik, Lauenburg/Elbe, Germany.

A known design of ship while breaking ice makes periodic pitching movements that occur approximately in synchronism with the natural frequency of oscillation of the craft. A further improvement according to this invention is effected by causing the craft, while breaking the ice to make periodic pitching movements, the frequency of which approximates as closely as possible to that determined by the rigidity of the ice to be broken. The devices used for this purpose and adapted to produce periodic pitching movements are adjusted to this frequency. In both constructions, the shape and mass of the ship affect the frequency to which adjustment is to be made. According to the invention the devices for producing the forces are concentrated in, at, or forward of the bow. The direction of these forces is made vertical, i.e. perpendicular to the ice layer, for instance by oppositely rotating out-of-balance weights the phase of which is made such that their effects neutralise one another in a horizontal direction but reinforce one another in a vertical direction. Apparatus for producing vertical pitching forces in the bow is illustrated by way of example in the specification.—*September* 20, 1961.

FOUNDRY EQUIPMENT

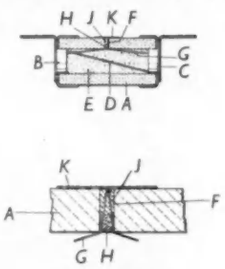
877,857. April 21, 1959.—APPARATUS FOR PACKING OR DENSIFYING SAND CASTING MOULDS, Bayerische Berg-, Hutten- und Salzwerke Aktiengesellschaft,16, Ludwigstrasse, Munich 34, Germany.

According to this invention, a method of making a sand casting-mould includes adding sand to a mould box, shaking or vibrating the whole box, applying to the free surface of the sand a downward pressure and applying separately to one or more areas of the sand in the mould box a ramming force while the shaking or vibrating is continued. Localised compression or densification of the sand is caused in the region of those areas by the intermittent additional compression effected by the ramming force in conjunction with the shaking or vibration. In the apparatus for carrying out the method a main pressure member is arranged to apply a downward pressure on the free upper surface of the sand in the mould box. At least one additional pressure member carried by the main member is moved relative to the main member to penetrate into the sand, and cause localised compression or densification below the surface of the sand. Drawings are given of a ramming block for use in apparatus according to the invention.—*September* 20, 1961.

ELECTRICAL ENGINEERING

877,941. December 10, 1958.—ELECTRIC CARTRIDGE FUSES, The General Electric Company, Ltd. Magnet House, Kingsway, London, W.C.2. (*Inventor : William James Elliott.*)

This invention relates to electric cartridge fuses having a tubular body of insulating material and an explosive type fuse indicating arrangement. With such arrangements there has always been the risk that the operation of the indicating arrangement may itself impair the protective value of the fuse by providing a conducting track-over path between the ends of the fuse. One object of the present invention is to provide an improved form of electric cartridge fuse having a fuse indicator which substantially eliminates this risk. Referring to the drawings, of which the lower one shows the indicator in detail, the cartridge fuse has a hollow cylindrical porcelain body *A* with two metal end caps *B*, *C*. Between these two caps and running down the hollow in the centre of the fuse body is the main fuse wire *D* the rest of the hollow being filled with a fusible silicate *E*. At a point about midway between the two end caps a small hole *F* is bored right through the wall of the fuse, so that it lies transverse to the axis of the fuse. Into this hole an indicator wire *G* is led in the form of a loop from the inside of the fuse and this is also joined to the two end caps so that it runs in parallel with the main fuse wire. The indicator wire is of a much smaller gauge than the main fuse wire since it is not intended to carry the main burden of the current. The loop of the indicator wire passing into the hole *F* is arranged so that the wire does not project out of the body of the fuse. This loop is sealed in the hole by means of a cement plug *H* at the bottom of the hole *F* and the hole is filled with an explosive powder *J* around the indicator wire. The loop is drawn up into the hole first and then pushed back into the explosive after filling. When the hole



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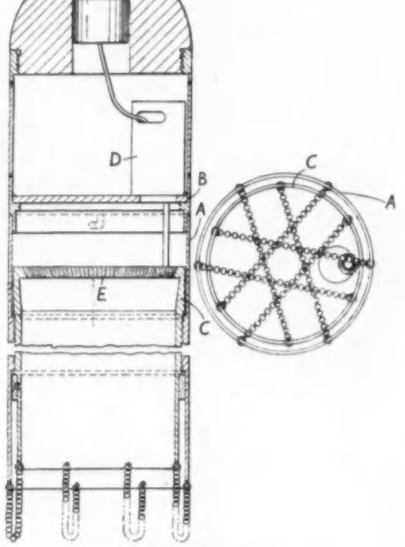
has been filled with the explosive powder it is covered by a disc of paper *K* which may be in the form of a label. When the curent grows too great, the main fuse wire melts and the heat of melting fuses the silicate surrounding it to form into a very high resistance, the current is therefore mainly concentrated in the indicator wire *G* and this melts due to the increased current through it. The heat generated through the indicator wire on melting is sufficient to ignite the explosive powder *J* and this explodes and the force of the explosion ejects the products of the explosion out of the front of the hole *F*, breaking through the paper *K* covering the hole. The explosive powder is arranged so that the products of the explosion are ejected with sufficient force from the fuse so as to fall clear of the fuse and not to contaminate its surface, thereby avoiding any risk of track-over between the two end caps. The fact that the fuse has blown can be readily noted by visual inspection since the paper disc covering the hole is now torn and charred. The advantage of this type of fuse indicator is that whereas in previous types where the indicator was led over a bridge in the wall of the fuse and two holes were needed in the wall for the entry and exit of the indicator, thereby necessitating a larger hole, the use of a smaller hole now results in a smaller fuse unit being able to be used, other considerations also being taken into account, since the length of fuse body between end caps necessary to provide an insulating surface long enough to obviate tracking is reduced to a minimum. —*September* 20, 1961.

MECHANICAL HANDLING

877,620. June 10, 1958.—LIFTING MECHANISMS, United Kingdom Atomic Energy Authority, London. (*Inventor : Charles John MacFarlane.*)

During the operation of a nuclear reactor it may be necessary to remove extraneous objects from the fuel element or control rod channels in the core of the reactor. It is required that such operations be effected remotely owing to the hazards arising from radiation, &c. This invention provides a grab suitable for such operations and for similar operations where remote handling is required in a narrow channel. The grab has a mild steel body and a mild steel sleeve *A* is bayonet fitted to an end fitting *B* welded to the body. A sleeve *C* coaxial with the sleeve is rotatably supported by ball bearings in spaces between the sleeves. Six chains each connect between the lower end of the sleeve *A* and the corresponding end of the sleeve *C*. A plate welded in the end fitting *B* carries a geared electric motor *D*, the shaft of which carries a bevel gear which engages with an internal gear *E* integral with the sleeve *C* In the removal of an object from a fuel element channel in the core of a reactor it is assumed that the grab is in the condition shown i.e. the sleeves are in such a relative position that the chains are hanging in loops leaving the lower end open. The grab is lowered down the fuel element channel to a position where the object is located within the sleeve *C* which is then rotated to the position shown in the side view where the chains span the end of the sleeve thus retaining the object on raising the grab. To provide the lateral location of the grab within the fuel element channel the sleeve *A* is made only slightly less in diameter than the channel.—*September* 20, 1961.



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Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office no later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

To-day, Oct. 27.—COVENTRY AND DISTRICT BRANCH : Conservative Rooms, 16, Queens Road, Coventry, "The Revision of British Standards and their Effect on Motor Applications," F. T. Bartho, 8 p.m. ★ STOKE AND CREWE BRANCH : Royal Hotel, Crewe, "The Lighting of Offices," D. Whipp, 7.30 p.m.
Tues., Oct. 31.—LEICESTER BRANCH : Westcotes Constitutional Club, 124, Wilberforce Road Leicester, Films, 7.30 p.m.
Wed., Nov. 1.—LIVERPOOL AND DISTRICT BRANCH : Visit to Sutton Manor Colliery, St. Helens, Lancs., 6 p.m. ★ NORTH LONDON BRANCH : Wood Green Civic Centre, Wood Green, London, N.22, "Electrical Aspects of Process Control," W. C. Hankins, 8 p.m. ★ MANCHESTER BRANCH : N.W. Electricity Board Service Centre Theatre, Town Hall Extension, St. Peter's Square, Manchester, 2, "Static Switching Control Systems," B. A. W. Midgley, 7.30 p.m. ★ PORTSMOUTH AND DISTRICT BRANCH : R.A.F.A. Club, Cosham, Portsmouth, Films, 7.30 p.m. ★ PRESTON BRANCH : Farmer's Arms Hotel, Market Street, Preston, "Industrial and Commercial Lighting Fittings," A. G. Smith, 7.30 p.m.
Thurs., Nov. 2.—BRIGHTON, HOVE AND DISTRICT BRANCH : Cricketers Hotel, Black Lion Street, Brighton, 1, "Electricity Supply Regulations," 7.30 p.m.
Fri., Nov. 3.—LIVERPOOL AND DISTRICT BRANCH : Industrial Development Centre, M.A.N.W.E.B., Paradise Street, Liverpool, 1, "Current Practice and Recent Trends in Cable Joints and Terminations up to 11kV," H. Flack, 7.30 p.m.

BRITISH INSTITUTION OF RADIO ENGINEERS

Wed., Nov. 1.—EDUCATION AND TRAINING COMMITTEE : London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1, "The Teaching of the Theory of Transistors and other Semiconductor Devices," M. R. Gavin, 6 p.m. ★ WEST MIDLANDS SECTION : College of Technology, Wolverhampton, "Electronics in Biological Engineering," W. J. Perkins, 7 p.m.
Thurs., Nov. 2.—SOUTH MIDLANDS SECTION : Winter Gardens, Malvern, "Transistor Portables," R. A. Lampitt, 7 p.m. ★ NORTH WESTERN SECTION : Reynolds Hall, College of Technology, Manchester, "V.H.F. Communications Receivers and Transmitters using Transistors," A. J. Rees and D. C. Carey, 7 p.m.

CEMENT AND CONCRETE ASSOCIATION

Wed., Nov. 1.—Harris College, Corporation Street, Preston, "Essentials of Good Concreting," E. E. H. Bate, 7 p.m.

CHEMICAL SOCIETY

Thurs., Nov. 2.—LONDON BRANCH : Queen Mary College, London, Symposium on "Electron-spin Resonance," 2 p.m.

COMBUSTION ENGINEERING ASSOCIATION

Wed., Nov. 8.—SCOTTISH REGION : Grand Hotel, Charing Cross Glasgow, Discussion on "The Design and Installation of Industrial Boiler Plants," opened by A. F. Webber, 10 a.m.

ILLUMINATING ENGINEERING SOCIETY

Wed., Nov. 1.—SWANSEA GROUP : Demonstration Theatre, South Wales Electricity Board, The Kingsway, Swansea, "The New I.E.S. Code," W. E. Harper, 6 p.m. ★ NEWCASTLE UPON TYNE CENTRE : Room B7, Percy Building, King's College, Queen Victoria Road, Newcastle upon Tyne, 1, Symposium on "Office Lighting," J. K. Boud and E. B. Sawyer, 6.15 p.m. ★ EDINBURGH CENTRE : Y.M.C.A., 14, South St. Andrew Street, Edinburgh, "The Association of Light and Colour," A. D. Charters, 6.15 p.m.
Thurs., Nov. 2.—NOTTINGHAM CENTRE : Electricity Centre, Carrington Street, Nottingham, "Traffic Signals," B. M. Cobbe, 6 p.m.

INSTITUTE OF MARINE ENGINEERS

To-day, Oct. 27.—SOUTH WALES SECTION : Technical College, Mount Pleasant, Swansea, Brains Trust, 6 p.m.
Thurs., Nov. 2.—NORTH EAST COAST SECTION : Stephenson Building, King's College, Claremont Road, Newcastle upon Tyne, "Pollution of the Sea by Oil," E. Douglas and I. G. Elliott, 6.15 p.m.
Mon., Nov. 6.—MERSEYSIDE AND NORTH WESTERN SECTION : Liverpool Engineering Society, The Temple, Dale Street, Liverpool, "Observations on the Design and Construction of the N.S. 'Savannah'," J. A. Dodd, and S. Macdonald, 6 p.m. ★ STUDENT LECTURE : Memorial Building, 76, Mark Lane, London, E.C.3, "The First Principles of the Diesel Engine and its Development for Use in Marine Work," G. S. Mole, 6.30 p.m.
Tues., Nov. 7.—JUNIOR LECTURE : East Ham Technical College, Barking Road, London, E.6, "Construction of the Ship," G. Ridley Watson, 7 p.m. ★ DEVON AND CORNWALL SECTION : Technical College, Falmouth, "The Layout and Operation of Marine Steam Turbine Machinery," D. M. V. Parkinson, 7 p.m.
Wed., Nov. 8.—SCOTTISH SECTION : Weir Hall, The Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, C.2, "The Development of Heavy Duty Marine Diesels During the Past Five Years," W. Kilchenmann, 7.30 p.m.

INSTITUTE OF METALS

Wed., Nov. 1.—MANCHESTER METALLURGICAL SOCIETY : Manchester Literary and Philosophical Society, George Street, Manchester, "Problems Associated with the Welding of Heavy Sections," A. F. Gifford, 7.15 p.m.
Thurs., Nov. 2.—LONDON LOCAL SECTION : Royal School of Mines, London, S.W.7, "The Design of Strong Materials," A. H. Cottrell, 7 p.m.
Tues., Nov. 7.—SOUTH WALES LOCAL SECTION : College of Technology, Swansea, Discussion on "Extrusion," and "Hot Extrusion of Non-Ferrous Metals," A. R. E. Singer, 6.30 p.m.

INSTITUTE OF PETROLEUM

Tues., Oct. 31.—CADMAN MEMORIAL MEDAL AND LECTURE : Royal Institution, London, "The Birth of a Science," Sir Stephen Gibson, 4 p.m.
Wed., Nov. 1.—61, New Cavendish Street, London, W.1, "Molybdenum Disulphide as a Lubricant Additive in Rolling Contact—A Study of Compatibility with other Additives," D. Scott and D. Jamieson, 5.30 p.m.

INSTITUTE OF PHYSICS AND THE PHYSICAL SOCIETY

Fri., Nov. 3.—SOUTH WESTERN BRANCH : The University, Exeter, "The Massbauer Effect," G. Lomer, 7 p.m.

INSTITUTE OF REFRIGERATION

Thurs., Nov. 2.—National College for Heating, Ventilating, Refrigeration and Fan Engineering, Borough Polytechnic, Borough Road, London, S.E.1, "Modern Designs in Thermostatic Control for Refrigeration, Including Air-Conditioning, Automatic Defrosting and Heat Pump Applications," J. E. Kumler, 7 p.m.

INSTITUTION OF CHEMICAL ENGINEERS

To-day, Oct. 27.—SCOTTISH BRANCH : Royal College of Science and Technology, Glasgow, "Problems in Evaporation," H. D. MacMurray, 7.30 p.m.
Tues., Oct. 31.—CARDIFF GROUP : South Wales Institute of Engineers, Park Place, Cardiff, "Ion Exchange in the Atomic Industry," T. V. Arden, 7.15 p.m.
Thurs., Nov. 2.—SCUNTHORPE GROUP : Royal Hotel, Grimsby, Joint Meeting with the Grimsby Institution of Engineers and Shipbuilders, "Accelerated Freeze Drying," K. Wood, 7.30 p.m.

INSTITUTION OF CIVIL ENGINEERS

Tues., Oct. 31.—Great George Street, Westminster, London, S.W.1, "Western Avenue, Lagos : The Design and Construction of a Soil Cement Pavement," C. M. Johnston, 5.30 p.m.
Thurs., Nov. 2.—Great George Street, Westminster, London, S.W.1, Discussion on "Foundation Design and Construction," introduced by D. J. Henfel, 5.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

To-day, Oct. 27.—NORTH SCOTLAND SUB-CENTRE : Robert Gordon's Technical College, Aberdeen, Sub-Centre Chairman's Address, G. L. Doig, 7.30 p.m. ★ SOUTHERN CENTRE : S.E.B. Showrooms, Newport, I.O.W., "Safety in the Utilisation of Electricity," S. J. Emerson, 6.30 p.m. ★ SOUTHERN CENTRE : South Dorset Technical College, Weymouth, "The Psychology of Study," C. A. Mace, 6.30 p.m.
Sat., Oct. 28.—LONDON GRADUATE AND STUDENT SECTION : Visit to British Railways Signalling School, Clapham Junction, 2.30 p.m.
Tues., Oct. 31.—EAST MIDLAND ELECTRONICS AND CONTROL GROUP : Lecture Theatre, College of Further Education, Greenclose Lane, Loughborough, Chairman's Address, "Trends in Automation," D. R. Hardy, 6.30 p.m.
Wed., Nov. 1.—I.E.E. AND R.AE.S. LONDON JOINT GROUP : Savoy Place, London, W.C.2, "Generation of Power in Satellites," H. J. H. Sketch, 6 p.m. ★ LONDON GRADUATE AND STUDENT SECTION : Visit to Johnson and Phillips Ltd., 2.30 p.m. ★ NORTH-EASTERN CENTRE : Conservative Club, Pilgrim Street, Newcastle, "The Potentialities of Artificial Earth Satellites for Radio-communication," W. J. Bray, and "The Interdependence of Civil and Electrical Engineering on the Continent To-day," F. C. Greenfield, 7 p.m. ★ TEES-SIDE SUB-CENTRE : Cleveland Scientific and Technical Institution, Middlesbrough, "Thermistors—Their Theory, Manufacture and Application," R. W. A. Scarr and R. A. Setterington, 6.30 p.m. ★ SOUTH-WEST SCOTLAND SUB-CENTRE : Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, C.2, "Some Notes on the Electrical Requirements of General Cargo Docks," E. R. Radway, 6 p.m. ★ SOUTHERN CENTRE : The University, Southampton, "Brushless Variable Speed Induction Motors Using Phase-Shift Control," F. C. Williams, E. R. Laithwaite, J. F. Eastham and W. Farrer, 7 p.m.
Thurs., Nov. 2.—Savoy Place, London, W.C.2, Special General Meeting, 5 p.m., Ordinary Meeting, "Acoustics and the Electrical Engineer," T. Somerville, 6 p.m. ★ LONDON GRADUATE AND STUDENT SECTION : Visit to Waterloo Station Signal Box, 7 p.m. ★ NORTH MIDLAND CENTRE : Chemistry Lecture Theatre, The University, Leeds, "Blaenau Ffestiniog and other Medium-Head Pumped Storage Schemes in Great Britain," H. Headland, 6.30 p.m.
Fri., Nov. 3.—MEDICAL ELECTRONICS DISCUSSION GROUP : Savoy Place, London, W.C.2, Discussion on "Information Theory in Relation to Biology," opened by D. M. Mackay, 6 p.m.
Sat., Nov. 4.—LONDON GRADUATE AND STUDENT SECTION : Visit to Big Ben Clock Tower, 10.30 a.m.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND

Tues., Nov. 7.—39, Elmbank Crescent, Glasgow, C.2, Informal Meeting, 6.30 p.m.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS

Wed., Nov. 1.—Institution of Mechanical Engineers, 1, Birdcage Walk, London, S.W.1, "Basic Principles of Control Application with Explanation of a Complex Job Breakdown," D. H. Powell and C. W. Spangle, 6 p.m.

INSTITUTION OF HIGHWAY ENGINEERS

Thurs., Nov. 2.—YORKSHIRE AND LINCOLNSHIRE BRANCH : Technical College, Lincoln, "The Laboratory and the Motorway," G. R. Forrester, 7 p.m.
Fri., Nov. 3.—LONDON BRANCH : Institution of Structural Engineers, 11, Upper Belgrave Street, London, S.W.1, "The Economic Justification of Roads," C. T. Brunner, 5.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

Mon., Oct. 30.—THERMODYNAMICS AND FLUID MECHANICS GROUP : 1, Birdcage Walk, Westminster, London, S.W.1, Discussion on "The Extent to which the Institution should Contribute to the Availability of Design Data and Information in Thermodynamics and Fluid Mechanics," 6 p.m.
Tues., Oct. 31.—STEAM PLANT GROUP : 1, Birdcage Walk, Westminster, London, S.W.1, "The Varieties of Feed Pump Drives," 6 p.m. ★ COVENTRY A.D. CENTRE : Hotel Leofric, Coventry, Repetition of Chairman's Address, 7.15 p.m.
Wed., Nov. 1.—NORTH WESTERN BRANCH : Walker Lecture Theatre, The University, Liverpool, "Blade Profiles for Axial Flow Fans, Pumps, Compressors, &c.," A. D. S. Carter, 6.30 p.m. ★ EASTERN GRADUATES' BRANCH : College of Technology, Luton, "Transmission Trends," B. C. Mills, 7.30 p.m. ★ EASTERN GRADUATES' BRANCH : Technical College and School of Art, Cambridge, Joint Meeting with the Local Graduates' Branch of the Institution of Electrical Engineers, Films, 7.30 p.m. ★ EAST MIDLANDS GRADUATES' BRANCH : College of Further Education, Grantham, "An Investigation into the Thermal Strain Properties of Cast Iron," S. Baker, 7.15 p.m. ★ NORTH WESTERN GRADUATES' BRANCH : Visit to Wilson's Brewery, Newton Heath, Manchester, 6.30 p.m.
Thurs., Nov. 2.—PROCESS ENGINEERING, REFRIGERATION, VENTILATION AND VACUUM PLANT GROUP : 1, Birdcage Walk, Westminster, S.W.1, "Problems of Maintenance in the Petroleum and Kindred Industries," 6 p.m. ★ MIDLAND BRANCH : Matthew Boulton Technical College, Suffolk Street, Birmingham, "Management in a Competitive World," W. J. Carron, 6.30 p.m. ★ NORTH WESTERN BRANCH : Engineers' Club, Albert Square, Manchester, "The Potentialities of Accurate Measurement and Automatic Control in Engineering Manufacture," J. Loxham, 6.45 p.m. ★ SCOTTISH BRANCH : Royal College of Science and Technology, Glasgow, "Closed Cycle Gas Turbine Development for Low-Grade Fuels," W. Connell, 7.30 p.m. ★ SOUTHERN BRANCH : Adelphi Hotel, Brighton, Repetition of the James Clayton Lecture, "Machine Tool Research, Design and Utilisation," D. F. Galloway, 7.30 p.m. ★ YORKSHIRE BRANCH : Chemistry Lecture Theatre, The University, Leeds, "Blaenau Ffestiniog and other Medium-Head Pumped Storage Schemes," H. Headland, 6.30 p.m. ★ YORKSHIRE GRADUATES' BRANCH : Works of Samuel Osborne Ltd., Sheffield, "Precision Moulding Techniques," E. Mackenzie, 6.45 p.m.
Fri., Nov. 3.—SCOTTISH BRANCH : Technical College, Dundee, "Closed-cycle Gas Turbine Development for Low-Grade Fuels," W. Connell, 7.30 p.m.

INSTITUTION OF PLANT ENGINEERS

To-day, Oct. 27.—BIRMINGHAM BRANCH : Imperial Hotel, Temple Street, Birmingham, "High Pressure Hot Water Heating," P. Marshall, 7.30 p.m.
Mon., Oct. 30.—WEST AND EAST YORKSHIRE BRANCH : Houldsworth School of Applied Science, The University, Leeds, "British Development of Hovercraft," R. A. Shaw, 7.30 p.m.
Tues., Oct. 31.—LONDON BRANCH : Royal Society of Arts, John Adam Street, Strand, London, W.C.2, "Tower Cranes—Their Use in Multi-Storey Construction," A. G. Stone, 7 p.m.
Wed., Nov. 1.—LEICESTER BRANCH : Grand Hotel, Leicester, "Development of Oil-Cooled Rotary Portable Compressors," P. C. Bevis, 7.30 p.m. ★ SOUTHERN BRANCH : Royal Beach Hotel, Southsea, "My Job," A. G. Williams, 7.30 p.m.
Thurs., Nov. 2.—BIRMINGHAM BRANCH : Hotel Leofric, Coventry, "Electrification of British Railways—Crewe to London," 7.30 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

Wed., Nov. 1.—NORTH MIDLANDS REGION : Reform Club, Victoria Street, Nottingham, "Fabrications in Aircraft Gas Turbine Engines," W. E. Corbitt, 7 p.m.
Thurs., Nov. 2.—NORTH WESTERN REGION : GRADUATE SECTION : Lecture Hall, Walker Art Gallery, Liverpool, Film, "Diesels," followed by a discussion, 6.30 p.m.
Sat., Nov. 4.—EAST AND WEST RIDINGS REGION : LEEDS GRADUATE SECTION : Visit to R. W. Crabtree and Sons Ltd., Water Lane, Leeds, 11, 10 a.m. ★ MIDLANDS REGION : COVENTRY GRADUATE SECTION : Visit to Jaguar Cars Ltd., Brown's Lane, Coventry, 9.45 p.m.
Mon., Nov. 6.—SOUTH EASTERN REGION : Royal Aeronautical Society, 4, Hamilton Place, London, W.1., "Cold Forging," F. Griffiths, 7 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

To-day, Oct. 27.—MIDLAND COUNTIES BRANCH : Byng Kenrick Suite, College of Advanced Technology, Birmingham, Chairman's Address, "Concrete—Past, Present and Future," J. E. C. Farebrother, 6.30 p.m.
Tues., Oct. 31.—NORTHERN IRELAND BRANCH : David Keir Building, Civil Engineering Department, Queen's University, Belfast, "The Structural Design of Merchant Ships," 6.30 p.m.
Wed., Nov. 1.—NORTHERN COUNTIES BRANCH : Neville Hall, Newcastle, "The Volta Bridge," C. R. Blackwell, 6.30 p.m. ★ EDINBURGH SECTION : North British Station Hotel, Edinburgh, "Cable Spinning on the Forth Road Bridge," H. Shirley Smith, 6 p.m. ★ WALES AND MONMOUTHSHIRE BRANCH : Mackworth Hotel, Swansea, Chairman's Address, E. Hughes, 6.30 p.m.
Fri., Nov. 3.—MIDLAND COUNTIES BRANCH : GRADUATES' AND STUDENTS' SECTION : Engineering Centre, Birmingham, "Proposed Bridge over the English Channel," A. R. Flint, 6.30 p.m. ★ SOUTH WESTERN COUNTIES SECTION : Grand Hotel, The Hoe, Plymouth, Chairman's Address, J. D. Norfolk, 6 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, Oct. 27.—Pepys House, 14, Rochester Row, Westminster, S.W.1, "The Influence of Aeroplane Design on the Economics of Air Transport," G. H. Lee, 7 p.m.
Fri., Nov. 3.—Pepys House, 14, Rochester Row, Westminster, London, S.W.1, Films, "You and the Silicones"; "Rubber from Rock," and "R. and D.," 7 p.m.

NEWCOMEN SOCIETY

Wed., Nov. 1.—Science Museum, South Kensington, London, S.W.7, "Gaspard Monge (1746–1818) and his Effect on Engineering Drawing and Technical Education," P. J. Brocket, 5.30 p.m.

NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

Mon., Oct. 30.—ANDREW LAING LECTURE : Literary and Philosophical Society's Lecture Theatre, Newcastle upon Tyne, "Aspects of Research in Marine Engineering," A. W. Davis, 6.15 p.m.

PLASTICS INSTITUTE

Tues. and Wed., Oct. 31 *and Nov.* 1.—Institution of Electrical Engineers, Savoy Place, London, W.C.2, Conference on "Engineering with Plastics," 9.30 a.m. both days.
Wed., Nov. 1.—NORTH EASTERN SECTION : Eldon Grill, Eldon Buildings, Grey Street, Newcastle upon Tyne, 1, "The Properties of Silicones and their Application," R. Nattrass, 7 p.m.
Thurs., Nov. 2.—SOUTHERN SECTION : Chemistry Dept., The University, Southampton, "Plastics and Other Non-Metallic Materials in Rocketry," P. Mullen, 7.30 p.m.

REINFORCED CONCRETE ASSOCIATION

Mon., Nov., 6.—NORTH WESTERN BRANCH : College of Technology, Sackville Street, Manchester, "Code of Practice CP 2007 (1960) Relating to Water Retaining Structures," A. W. Hill, 6.45 p.m.

ROYAL INSTITUTION OF GREAT BRITAIN

To-day, Oct. 27.—21, Albemarle Street, London, W.1, "Cosmic Rays from the Sun," M. A. Ellison, 9 p.m.

ROYAL INSTITUTION OF NAVAL ARCHITECTS

Mon. to Fri., Oct. 30 *to Nov.* 3.—Institute of Marine Engineers, 76, Mark Lane, London, E.C.3, Joint Symposium on "Welding in Shipbuilding," sponsored by The Institute of Welding, The Royal Institution of Naval Architects, The Institution of Engineers and Shipbuilders in Scotland, The North East Coast Institution of Engineers and Shipbuilders and The Institute of Marine Engineers.

ROYAL METEOROLOGICAL SOCIETY

Wed., Nov. 1.—49, Cromwell Road, London, S.W.7, "Giant Hail," F. H. Ludham, 5.30 p.m.

SOCIETY OF INSTRUMENT TECHNOLOGY

Mon., Nov. 6.—CONTROL SECTION : Manson House, 26, Portland Place, London, W. 1, "Semiconductor Diodes and Rectifiers in Control Engineering," P. R. Wyman, and "The Transistor in Control Engineering," G. D. Bergman, 6.30 p.m.

Advanced Engineering Courses

Methodology of Operational Research. UNIVERSITY OF BIRMINGHAM, Institute for Engineering Production, "Southfield," 16, Norfolk Road, Edgbaston, Birmingham, 15. Residential executive course, from November 13 to 24. The course has been designed for practitioners of operational research who are already familiar with such standard mathematical techniques as inventory theory, linear and dynamic programming, queueing theory, and so on; and who, in addition, have a working knowledge of probability theory and statistics. It will examine the research procedures employed in operational research and attempt to develop rational bases for selecting the best procedures in the context of practical problems. Where possible, mathematical models of research decisions will be constructed and optimal solutions will be derived, where not, the deficiencies in the current state of the art will be made explicit and the best qualitative basis for research decisions will be sought. Fee 60 guineas.

Analogue Computing Methods for Engineers. THE UNIVERSITY, SHEFFIELD. A four-day course commencing Tuesday, November 7, and covering the linear problem, fundamental principles, basic computer units, application to specific engineering problems, advantages and limitations, methods of recording results, dealing with non-linearities, and developments and trends. Fee £10.

Recent Advances in the Science of Materials. LANCASTER COLLEGE OF TECHNOLOGY, Coventry. A short course, Thursday and Friday, November 9 and 10, arranged in collaboration with the Department of Materials, College of Aeronautics, Cranfield, and intended for advanced students and graduates in science and engineering who wish to keep abreast of modern developments in technology. Fee £1 2s.